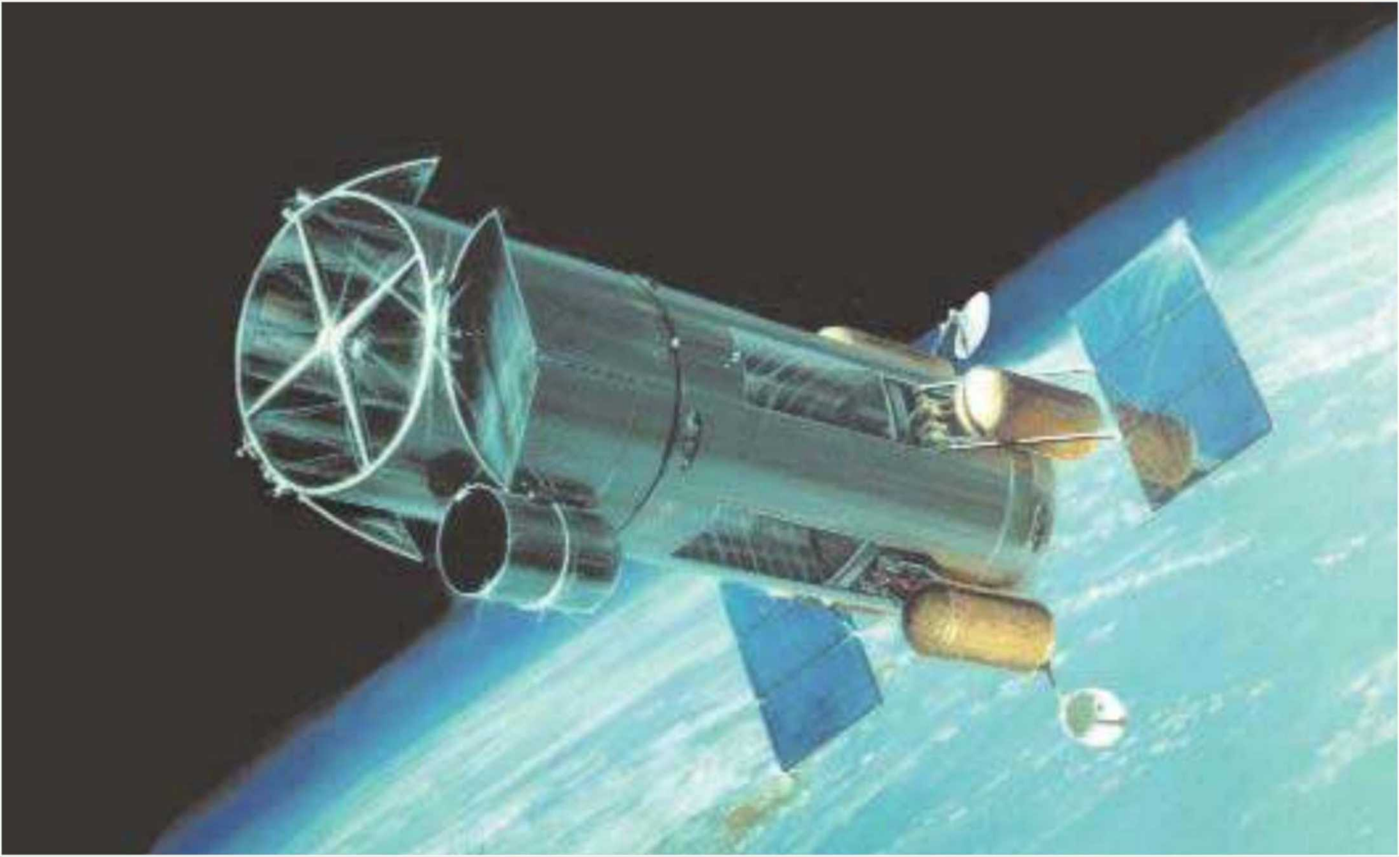
SECRET PROJECTS

MILITARY SPACE TECHNOLOGY



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BILL ROSE

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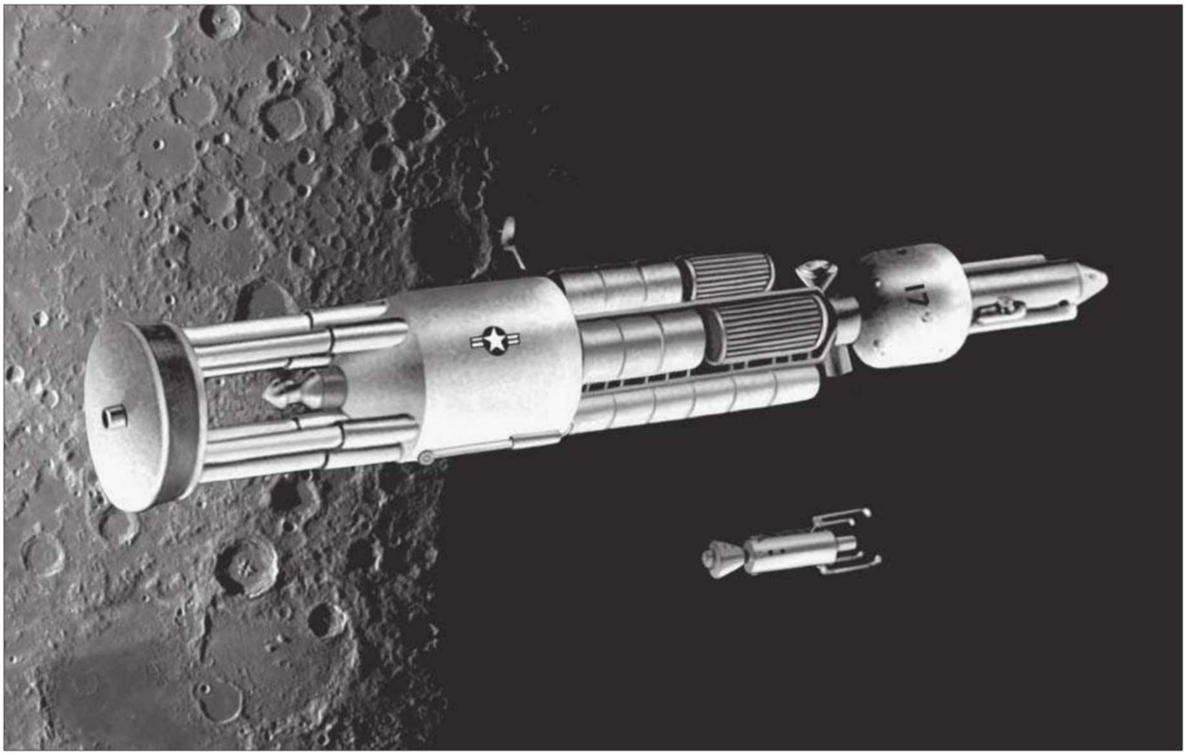

BILL ROSE

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Photograph on half-title page:
The successful launch of a captured German V-2 rocket during Operation *Backfire* in 1945. The V-2 ballistic missile revolutionised warfare and the technology eventually made manned missions beyond the Earth's atmosphere possible. Bill Rose

Photograph on title page:
Conceptual artwork showing one of the USAF's Orion spacecraft in orbit above the Moon. Huge nuclear powered military space vehicles are unlikely to become a reality in the foreseeable future. Bill Rose

Contents

Introduction 6

Chapter One **German Wartime Ambitions** 14

Chapter Two **British Space Ambitions** 41

Chapter Three **US Projects** 63

Chapter Four **Aurora, Myth or Reality?** 128

Chapter Five **Soviet Military Space Programmes** 143

Chapter Six **Nuclear Propulsion** 169

Chapter Seven **Destination Moon** 180

Glossary 190

Index 192

Introduction

'Space superiority is not our birthright, so we've got to work to make it our destiny.'

General Lance W Lord, Commander,
US Air Force Space Command,
Peterson Air Force Base, Colorado, USA. 2005

Since World War Two almost every important space programme or proposed project has involved some degree of secrecy, and this applies not just for military operations but also to aspects of seemingly open, large-scale civil undertakings like NASA's manned Moon programme. In many cases hugely expensive civil operations have carried unpublicised risks, drawn on a certain amount of military expertise, or generated new technologies with unforeseen potential to threaten national security. Sadly, most high profile space missions have tended to be flag waving exercises, with scientific achievement taking second place, although there are signs of a shift towards the greater commercial exploitation of space, which is likely to become evident once the US establishes a permanent base on the Moon.

The way we regard space flight has evolved considerably since it first caught the public's imagination. The outlandish idea of venturing beyond the Earth started to generate serious interest during the latter part of the Victorian era. This was a consequence of the publication of the sensational 1865 novel *From the Earth to the Moon* penned by Jules Verne (1828-1905). The popular French author was the first person to describe a trip to the Moon in semi-scientific terms and some aspects of this vision would prove amazingly prophetic.

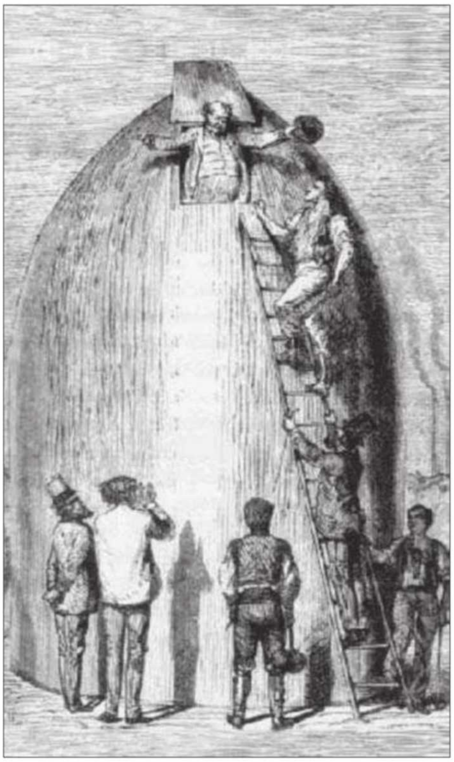
In Verne's story, a manned capsule was launched towards the Moon using a gigantic cannon located at Tampa, Florida, which is relatively close to Cape Canaveral where NASA's Moon missions began a century later. He described gravity and weightlessness, while also suggesting the use of retro-rocket braking and an ocean splashdown. The three-man spacecraft was similar in size to NASA's Apollo command module and Verne estimated that the project would cost roughly the same as NASA's Moonshot (in adjusted dollars of course). However, when he attempted to calculate the effects of using the 900ft (274m) long cannon, Verne made a few mistakes with the maths and seemed totally unaware that the massive acceleration would have instantly killed the crew members. Although many Victorian readers regarded Verne's novel as total fantasy, it set the scene for further stories.

Influenced by Verne's novel, the British science fiction author H G Wells (1866-1946) wrote *The First Men in the Moon*, which was published in 1901. This story depicted a spaceship covered with an exotic gravity shielding material called Cavorite, which was piloted to the Moon by the eccentric scientist Dr Cavor and his impoverished associate Mr Bedford.

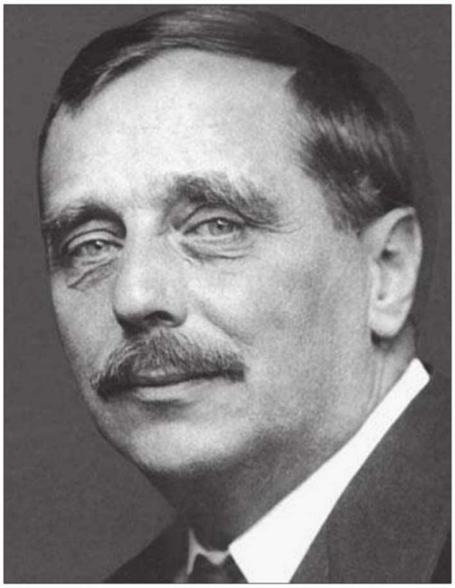
Although much of the technology described by Verne and Wells was impossible, serious research into space flight was already being undertaken by a brilliant Russian visionary called Konstantin Edvardovich Tsiolkovsky (1857-1935). A provincial maths teacher who suffered from a degree of deafness caused by a childhood illness, Tsiolkovsky developed a deep and enduring interest in science and engineering. In 1903 he completed a paper entitled *Exploring Space With Reactive Devices*, which explained how rocket propulsion would work in a total vacuum and outlined ideas for liquid fuel rocket propulsion. Tsiolkovsky established most of the basic scientific rules for practical space flight and went on to produce detailed descriptions of space suits, orbital platforms and multi-stage rockets.

As our scientific knowledge expanded, ideas about leaving the Earth's atmosphere using a purpose built machine began to take shape and it seemed that manned space flight might eventually become possible. In America during the early 1920s, rocket pioneer Robert Hutchings Goddard (1882-1945) undertook a series of somewhat crude, but nevertheless groundbreaking rocket experiments. These tests proved the viability of liquid propellants and his influence reached designers in Germany who began to scale up

Author Jules Verne, who became the first person to describe a Moon flight in semi-scientific terms.



An original drawing based on Verne's proposal for a space capsule designed to reach the Moon.
Both Bill Rose



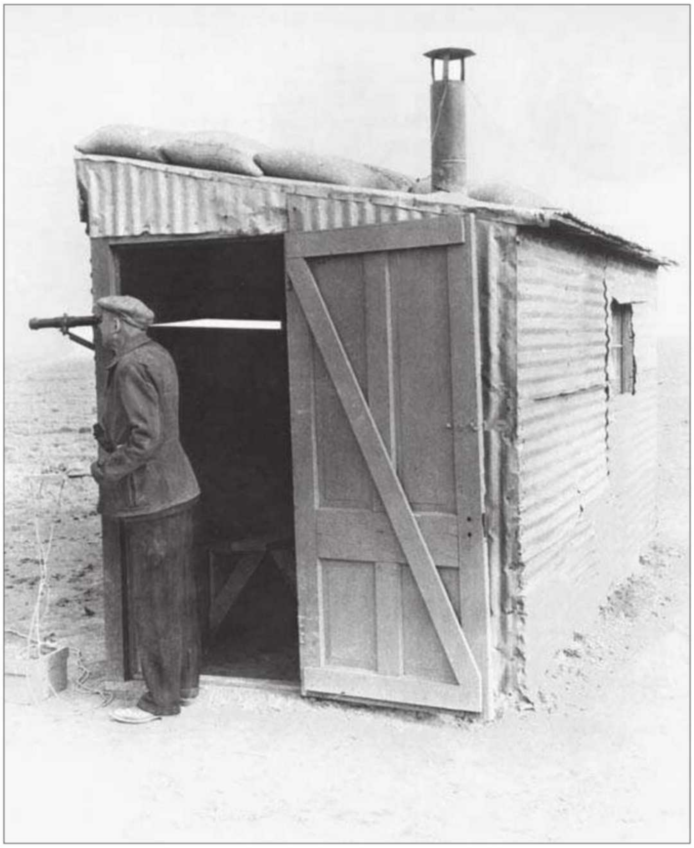
the research and seriously consider its future applications.

Pulp science fiction had already embraced the spaceship and during the late 1920s the German film industry turned its attention to making a serious movie about a flight to the Moon. To achieve a high level of credibility, its director Fritz Lang hired the Romanian born maths teacher Hermann Oberth (1894-1989) as a consultant. Oberth had written a book on space travel called *Die Rakete zu den Planetenreumen* (The Rocket into Interplanetary Space) which was published in 1922. Lang also recruited the science writer Willy Ley (1906-1969) as his second technical consultant and the finished movie, called

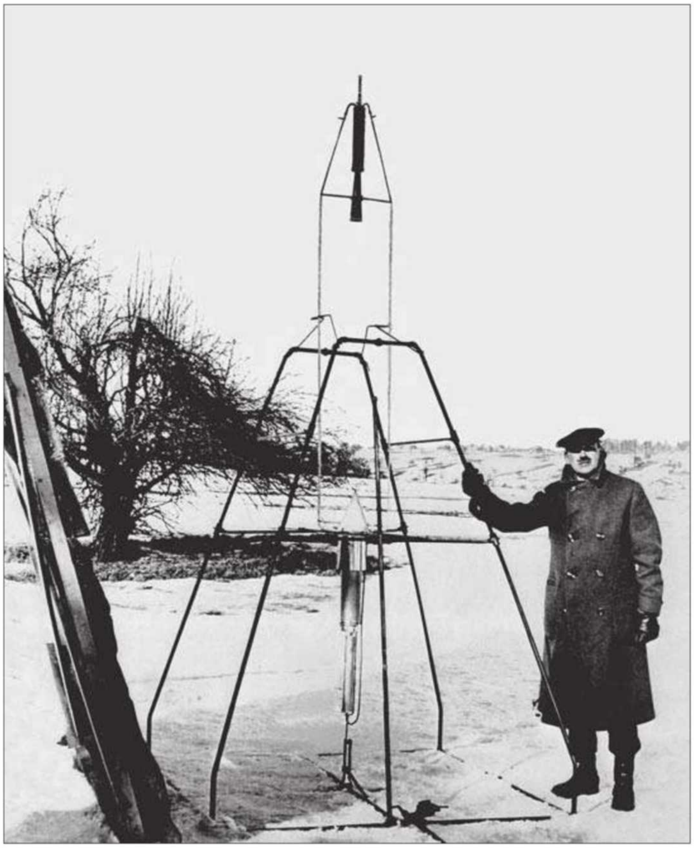
Above left: **British sci-fi author H G Wells, who did much to promote the idea of spaceflight during the late Victorian era.** Bill Rose

Above centre: **Konstantin Tsiolkovsky established most of the scientific principles of spaceflight before the 19th Century had ended.** Bill Rose

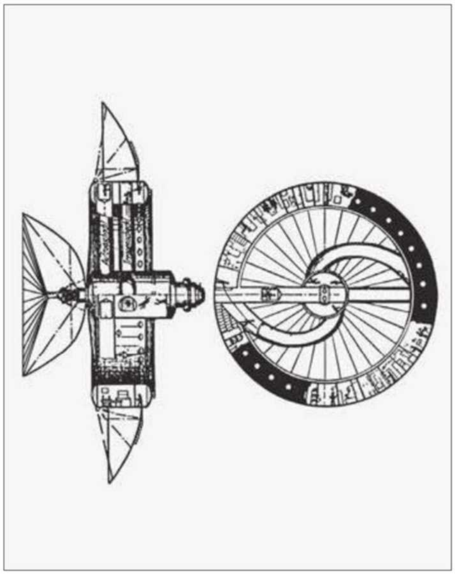
Above right: **The highly influential Romanian space pioneer Hermann Oberth.** Bill Rose

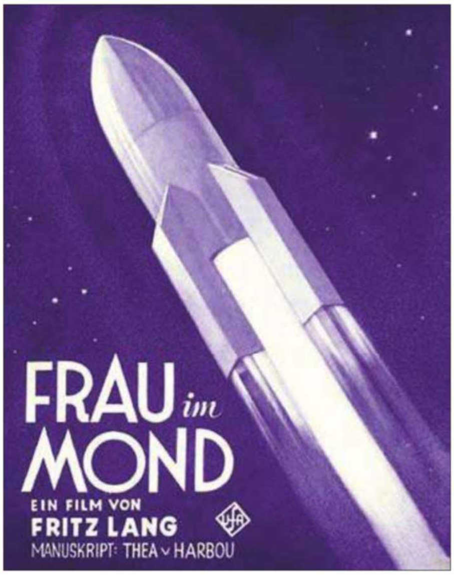


Above: **Mission control headquarters for Robert Goddard's rocket experiments during 1926.** NASA



Above: **American rocket pioneer Dr Robert Goddard stands beside a small liquid fuel rocket on 16th March 1926.** NASA

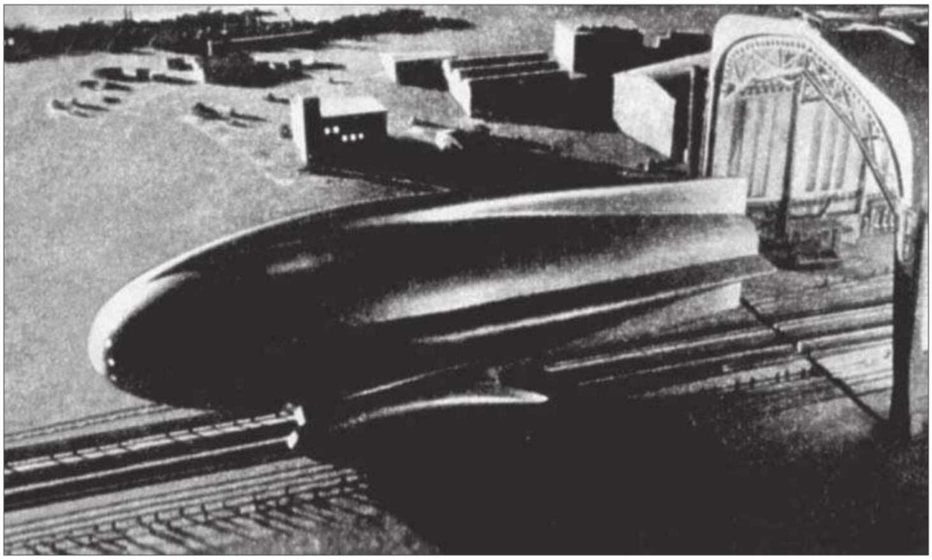




Far left: **An early design for a space station proposed by Hermann Noordung in 1928.** Bill Rose

Left: **After reading Hermann Oberth's book on space travel in the early 1920s, film director Fritz Lang set out to make a high quality motion picture of the first Moon mission. His influential film *Frau im Mond* set the standard until *Destination Moon* was released in 1950.** Bill Rose

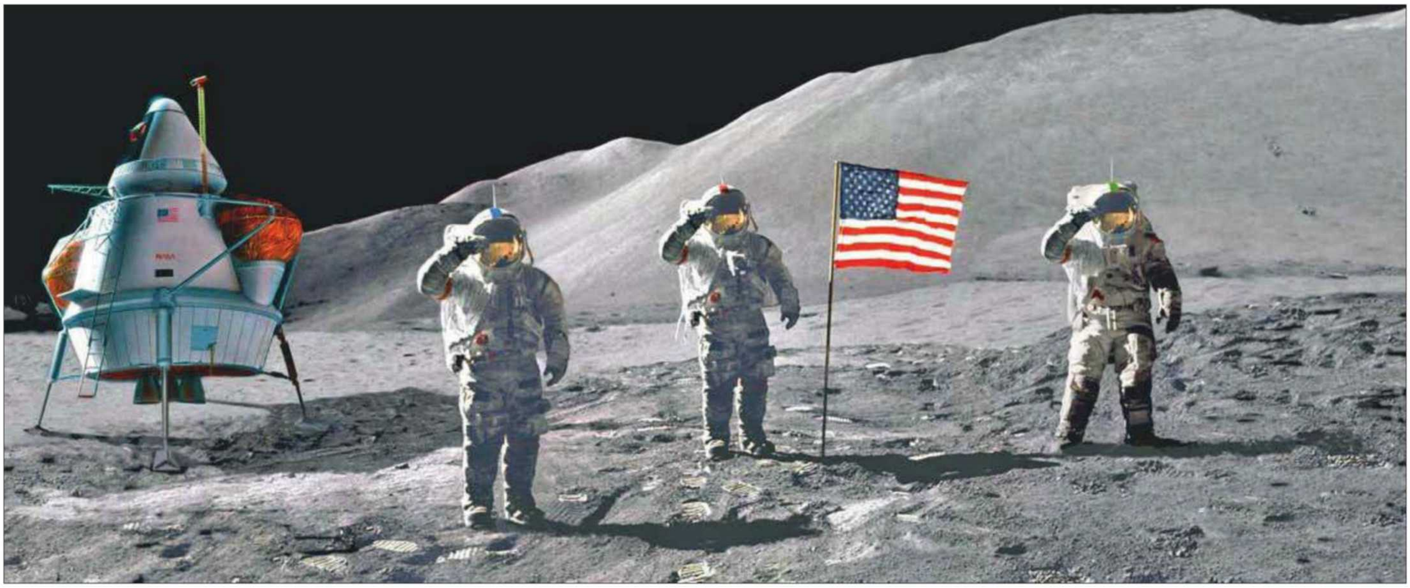
Below: **In 1937 work began at the Bavaria Studios on a film with the provisional title *Zwischenfall im Weltraum* (Incident in Space). At the same time another sci-fi movie was in production at Ufa Studios (Babelsberg) called *Weltraumschiff 18* (Spaceship 18). Both films were cancelled in 1939, but material from each production was cobbled together to form a new twenty-minute long film called *Weltraumschiff 1 Startet* (Spaceship 1 Launches), under the credited direction of Anton Kutter. Sometimes described as Nazi science fiction and often confused with *Frau im Mond*, the film portrays a flight around the Moon in the mid-1960s using a huge spaceship built by the Zeppelin Works at Friedrichshafen.** Bill Rose



Bottom: **Without Wernher von Braun and his V-2 rocket, the advent of space exploration would have been delayed by many decades. Only now would we be considering the first Moon mission, which is portrayed in this illustration.** Bill Rose

Frau im Mond (Woman in the Moon), was completed in 1929. Although it was not a massive hit (due to the fact that this was one of the last silent films to be made during a period of swift transition to sound) it still set the standard for cinematic science fiction productions until 1950.

By the 1930s the first serious scientific study of a Moon mission was being undertaken by a group within the British Interplanetary Society (BIS), who applied scientific and engineering principles to the design of a lunar rocket and landing vehicle. They came up



with a set of plans that were a little quaint, but not totally dissimilar to NASA's Apollo programme of the 1960s. Nevertheless, there was no huge industrial base to support such a venture and no substantial reserves of cash for an idea that was generally perceived as fairly pointless and unattainable within anyone's lifetime. It would take Germany's military rocket development during World War Two, and a few young visionaries like Dr Wernher von Braun (1912-1977), to bring the idea of manned space exploration to life and without any of this, a manned flight to the Moon and major advances in electronics would have been delayed by decades.

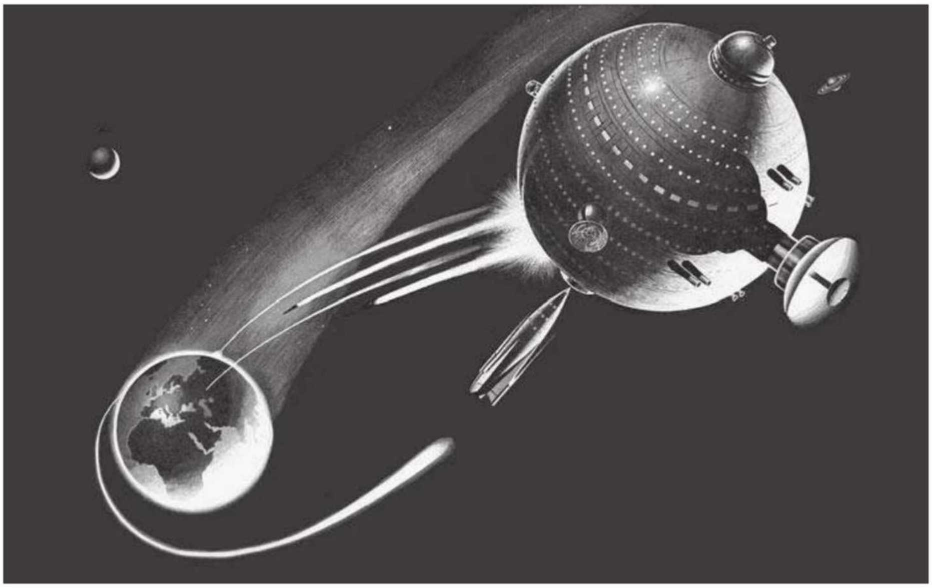
In the immediate Cold War years, captured rocket technology and the know-how of German scientists promised, for both sides of the divide, a long-range, unstoppable delivery system for the newly invented, ultra-destructive atom bomb (assuming that nuclear weapons could be scaled down in size). Further related military possibilities began to emerge from wartime German rocket research, which included submarine launched ballistic missiles, very high performance bombers and spyplanes capable of operating on the edge of the Earth's atmosphere. There was also the prospect of orbital satellites carrying film or television cameras which could look down on hostile nations and observe their activities. All of these systems would be virtually impossible to counteract, although it was clear they would cost a king's ransom to develop.

The Germans had been years ahead of the Allies in many areas of military technology and after the war neither East or West was fully aware of what had fallen into the opposition's hands, or just how advanced some of it might be. Dr Wernher von Braun and many members of his staff had surrendered to the Americans in 1945 and soon found themselves transported to the US where they were put to work on rocket development. A similar sized group of German scientists headed by Helmut Gröttrup (1916-1981) had been persuaded to work for the Soviets on a largely identical programme. Almost immediately, von Braun began to promote his personal space ambitions to senior Pentagon officials. Many of the things he had been unable to do in Germany were now being discussed as serious future possibilities, and there appeared to be no shortage of funding.

The Americans were increasingly alarmed by Soviet military developments and this was brought into sharp focus during 1949 when the Russians successfully tested a nuclear device, a step achieved years ahead of CIA predictions. Within the Pentagon, many proposals were considered that might eventually

Above left: **A late photograph of Wernher von Braun.** NASA

Above right: **A wartime German V-2 (A4) missile covered with a camouflaged shroud is transported by rail from an underground storage area.** Bill Rose



Right: **This artwork appeared with an article published in the April 1949 issue of the popular US magazine *Mechanix Illustrated*. Described as a 'Fortress on a Skyhook', the writer claimed that this 'Proto-Deathstar' could be used to launch nuclear missiles against any target on Earth. There is a suggestion that the battle station might be offered to the United Nations to deter war, but the idea strongly hints at future US ambitions for military dominance in space. This illustration by Frank Tinsley has been adapted from the original artwork and is used with the written permission of Charles Shopsin/Modernmechanix.com** provide the US with a significant military advantage and these included the exploitation of space. Hints of this thinking first surfaced in the classic 1950 Hollywood movie *Destination Moon*, directed by George Pal.

Scripted by the influential sci-fi author Robert Heinlein (1907-1988), *Destination Moon* opened with a group of American scientists deciding that their country must be the first in space. One of the characters says, 'If any other power gets into space before we do, we'll no longer be the United States, we'll be the disunited world.' With private funding they construct a 150ft (45m) long rocketship powered by an atomic engine and, eventually, four astronauts blast off for the Moon. Five years later George Pal produced the more ambitious movie *Conquest of Space*, which told the story of a manned mission to Mars during the mid 1980s. Based on Wernher von Braun's book *The Mars Project*, this film contained some well thought out technical ideas but was let down by a truly idiotic script. However, while *Conquest of Space* might be described as just another Hollywood sci-fi movie made in the 1950s, it reflected elements of US military thinking at that time and shows us that, behind the scenes, von Braun was actively shaping the Pentagon's space objectives. This included orbital supremacy by the early 1960s and a Moon landing before 1970.

It looked as if America would become the dominant power in space. However, when Sputnik 1 was launched into orbit by the USSR on 4th October 1957 this tiny satellite unexpectedly overturned the apple cart and raised many serious concerns. A nation of so-called Bolshevik peasants had put a small spacecraft into Low Earth Orbit (LEO), while subtly demonstrating their future ability to build spy satellites and rapidly deliver nuclear weapons to any location on Earth. Confirming America's worst fears, the Russians went on to place a much bigger spacecraft called Sputnik 2 into orbit on 3rd November 1957, and this vehicle carried a dog which was named Laika.

Unfortunately, the first American attempt to orbit an Earth satellite went disastrously wrong and, after further mishaps with the US Navy's Vanguard rockets, von Braun's Army group took over and finally launched the Juno 1 satellite into orbit on 31st January 1958. It was now very clear that the Soviets were rapidly moving towards a manned mission and if they managed to put an astronaut into space and bring him back in one piece, it would seriously damage American prestige. Although the Americans were working on a number of promising systems, the race for future space supremacy was under way and there were unpublicised fears in Washington that the Russians would develop a significant lead. This had to be matched or preferably surpassed because any significant Soviet advance might suddenly tip the balance of military power beyond the point of recovery.

Aside from the long held dream of putting a man into space, both sides were spending billions of dollars on the development of long-range strategic missiles, photo-reconnaissance satellites, orbital communication relays and ways to destroy enemy space platforms. By the late 1950s taking control of the high ground had become a priority. Man had yet to fly in space but Pentagon planners were looking far beyond this and preparing for the next two decades. Several black budget studies were under way and these included plans to build fortresses on the Moon that would house nuclear missiles capable of hitting targets on Earth, giant space stations and also concepts for nuclear powered spacecraft the size of naval destroyers.

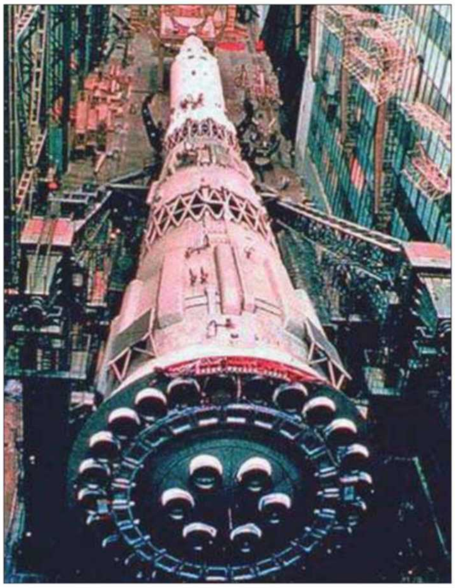
Whether or not any of these grand schemes was feasible is another issue. Most of them would have required the annual budget of a small nation to develop and they would have stretched the current levels of technical capability to the limit. As history later showed, the early military concerns about space becoming a new battleground were somewhat premature and perhaps as much as a century too early. Russia may have been the first nation to put a man into space but the Americans were close behind, although the Soviet success had a very positive effect on Washington who soon decided that no effort should be spared to put men on the Moon first. A massive civil programme was initiated for which NASA utilised some of the highly classified research undertaken by the US military to build bases on the Moon. However, the US Administration simply wanted to go there, take some pictures, gather a few samples and come back in one piece, whereas the Military's plans had been on a huge scale with entirely different motives.

Around the world, many observers continued to predict that Soviet cosmonauts would set foot on the Moon before the Americans, but the USSR's winning streak was about to end. In 1966 the chief Soviet rocket designer Sergei Korolev (1906-1966) died during what had started out as fairly routine surgery to remove a bleeding polyp from his intestine. It was later reported that the surgical team headed by Health Minister Boris Petrovsky had discovered a large malignant tumour which made the procedure almost impossible. Korolev had been the driving force behind Russia's space programme and his loss brought a significant decline in morale, and this was followed by the first of several disastrous attempts to launch the Soviet's new and massive N-1 booster, which was intended to rival NASA's Saturn V.

About to become the first man in space, on 12th April 1961 Colonel Yuri Gagarin (1934-1968) rides in a bus to the launch pad. Sitting directly behind him is the backup cosmonaut Gherman Titov (1935-2000), who would eventually be Russia's second man in space. ESA

Right: **On 25th May 1961 at a joint session of Congress, President Kennedy declared that 'I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the Moon and returning him safely to Earth.' It signalled the start of a hugely expensive civil programme that would see an American flag on the lunar surface by mid-1969.** The White House

Far right: **Russia's massive ill-fated N-1 Moon rocket.** NPO Energomash

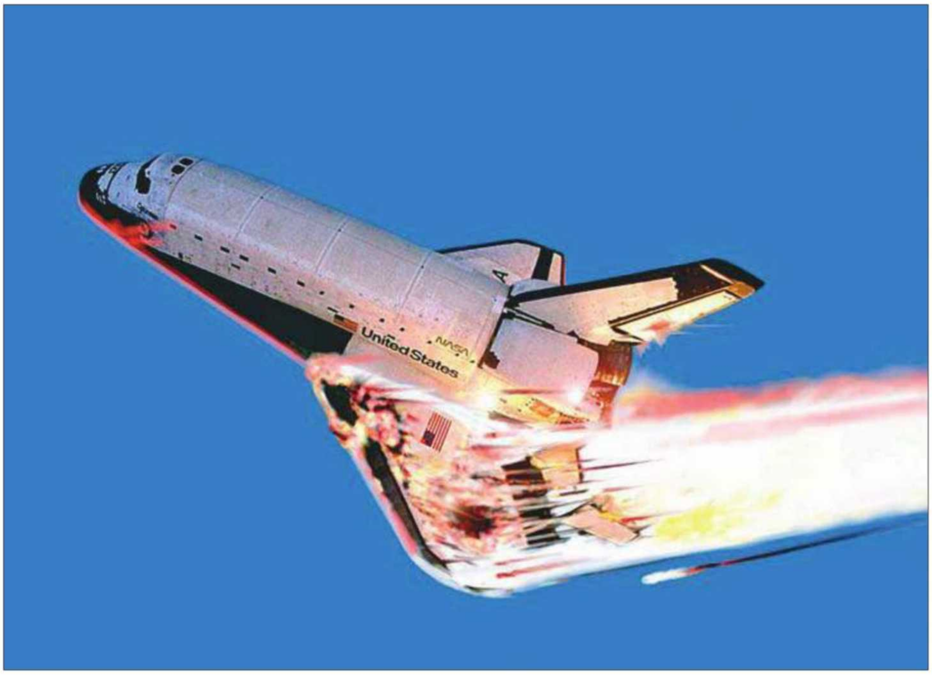


America had taken the lead and in 1969 two NASA astronauts set foot on the lunar surface, bringing the space race to an end. Although the Russians remained very secretive about their manned lunar project, they were expected to land on the Moon within weeks or months of Armstrong and Aldrin's historic mission. However, further N-1 launches were unsuccessful and, although the Russian Moon project remained active into the 1970s, it was effectively dead after the fourth failure of the N-1. This would have a direct impact on manned space exploration and the US no longer had a competitor to worry about. Soon unforeseen public apathy set in throughout America and this brought the Apollo Moon missions to an abrupt end in late 1972.

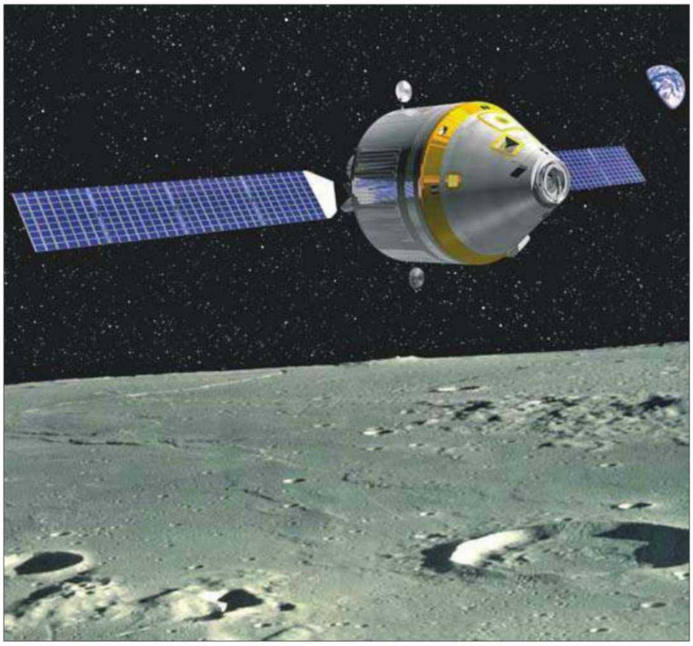
There were other contributory factors such as the hugely expensive war in Vietnam and, as a consequence, the whole process of space exploration slowed to a surprisingly sluggish pace. It seemed that Stanley Kubrick's dazzling vision of the early 21st Century portrayed in the 1968 movie *2001 – A Space Odyssey* was back on hold. In fact, much of what appeared in his groundbreaking film would be pushed at least fifty to one hundred years into the future. This dramatic slowing of the civil programme had a major impact on the US military's space plans, although the development of increasingly capable orbital surveillance systems continued and it was decided to go ahead with the Shuttle Orbiter. This largely reusable space transportation system promised much and it was expected to fulfil the role of an affordable dual-use manned vehicle, capable of undertaking a range of different civil and military missions. Unfortunately, various design compromises, budgetary controls and political interference would all play a major part in this complex spaceplane's downfall.

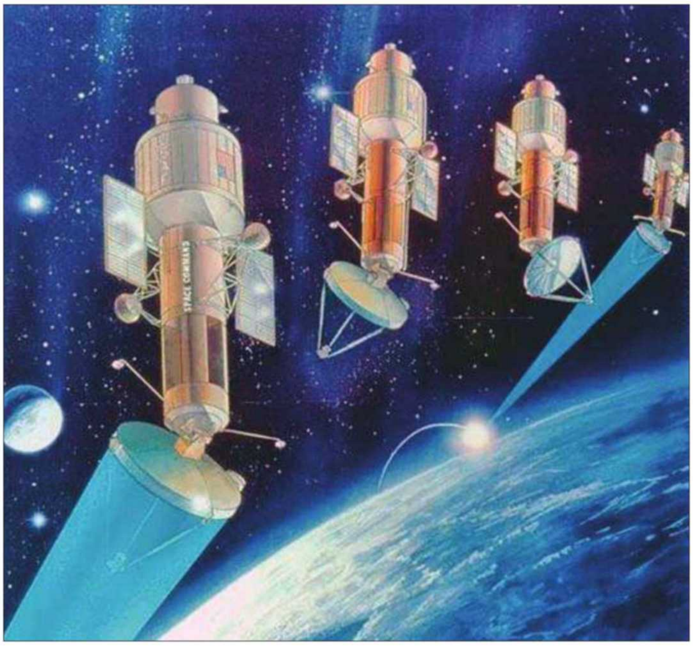
In Russia the US Shuttle programme was viewed with considerable suspicion and regarded as an advanced anti-satellite system or the means to deliver a surprise nuclear strike. As a consequence, attempts were made to match or counteract this US space capability with several different vehicle designs. This eventually led to the Buran Orbiter, which cost billions of roubles to develop and outwardly resembled the American Shuttle, although in fact it was different in many ways. One of these spacecraft achieved a remote control orbital flight and then the entire project was effectively scrapped as the Russian economy collapsed.

While the US Shuttle proved expensive and demanding to operate, the programme was also dealt a serious blow by the loss of Challenger and seven crew members on 28th January 1986 in a catastrophic explosion shortly after launch. This disaster was a substantial setback to the US manned spaceflight programme and left the USAF in a serious quandary about their future needs and capabilities. It is possible that, at this point, the USAF in conjunction with the CIA decided to proceed with the development of a deep black parallel capability, which remains under wraps. The loss of a second US Shuttle and its crew on 1st February 2003 almost brought NASA's ailing manned space programme to an end, and it led to the development of an ultra conservative manned replacement which is essentially a scaled-up and modernised Apollo capsule system.



The loss of the Space Shuttle Columbia during re-entry on 1st February 2003 (simulated in this illustration) came disastrously close to ending America's manned presence in space. Bill Rose





Another costly US endeavour was the Strategic Defense Initiative (SDI), which is more popularly known as 'Star Wars'. Heavily promoted by the 1980s Reagan Administration, this programme was sold to American taxpayers as a high-tech shield orbiting in space which would protect the country against missile attacks. However, many of the goals for this far-reaching programme were unaffordable, technically unattainable and still remain that way today.

In the course of half a century, the world has become highly dependent on space-based systems for communications, global positioning and observation. These satellites appear increasingly vulnerable to interference or disablement and there are ongoing concerns about who controls near-space. Within the next twenty to thirty years we can expect to see the space frontier pushed much further out. There will almost certainly be bases on the Moon operated by the United States and probably China in conjunction with Russia. Outwardly, these facilities will be built to further scientific causes, although no effort will be spared to secure exotic materials like Helium 3 for fusion powerplants back on Earth. Hidden ice deposits (which may be found at the poles) will prove invaluable for life support purposes and rocket propellant, while thorium (known to exist on the Moon) will be mined to fuel lunar-sited nuclear reactors. Almost inevitably, the military will extend their interests to protect these important assets and ensure the integrity of all transportation and communication pathways between the Earth and the Moon. Whether or not battles will eventually be fought in space, or on other worlds, remains an interesting question but, judging by mankind's track record, this seems almost inevitable!

So far, the history of space utilisation and exploitation has been patchy, with considerably less progress than might have been predicted half a century ago. As things stand at the moment, there is one incredibly expensive space station in orbit that still seems to be looking for a useful role. There is no fully operational single-stage-to-orbit (SSTO) spacecraft in service and there are no bases on the Moon. Cancelling the Apollo lunar programme, building the Space Shuttle, spending so much on the International Space Station (ISS) and scrapping the X-33 spacecraft, all appear to have been increasingly poor decisions by America.

The Russians have also made big mistakes, for example with the N-1 rocket and the Buran. While there has been little progress with their space programme since the fall of Communism, the Russians have maintained a very good record for launch reliability. Perhaps we shouldn't be too surprised that China with its booming economy has developed a space capability in such a short space of time. This country has serious ambitions in space, including a base on the Moon, and seems determined to achieve its goals.

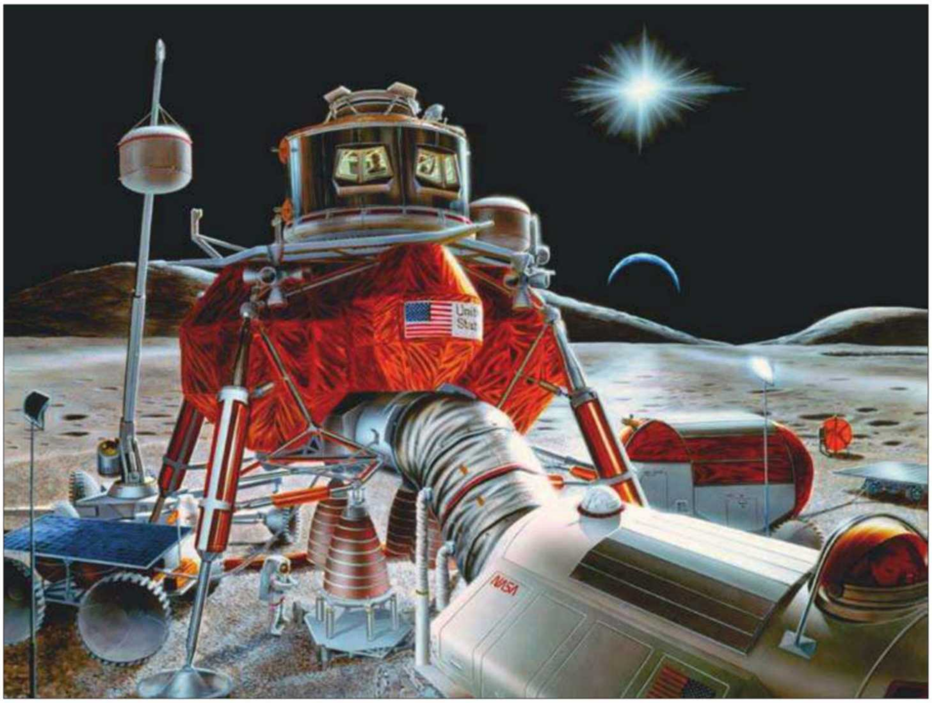
Although there is some overlap with civil space programmes in this book, I have tried

Top left: **The Orion Spacecraft (previously called the Crew Exploration Vehicle or CEV) is NASA's follow-on from the Space Shuttle and will allow ferry missions to the ISS, a return to the Moon and deep space missions.** NASA

Top right: **An aspiration of the 1980s Reagan Administration was a shield in space that would be capable of protecting America against nuclear missile attack. This would use equipment like these laser weapon platforms.** US DoD

Left: **These three secret US Naval Oceanic Surveillance Satellites (NOSS) travelling in formation were photographed by the author on 26th April 1992 as they passed over Eastern England in a highly inclined polar orbit. The ability to neutralise or destroy surveillance and communication satellites was an important concern for both superpowers before the space race officially began.** Bill Rose

Right: **A hypothetical next-generation US Moon Lander docked at a manned outpost.** NASA



to limit my discussion to military space projects with the emphasis on classified work. I have also endeavoured not to speculate too much on future developments, although you will find a few minor exceptions. Because I have concentrated on manned space flight, the discussion of ballistic missiles, spy satellites and automated vehicles is somewhat limited. The same goes for ground based anti-missile systems and unmanned orbital weapons proposed for President Reagan's SDI programme. To examine these areas in adequate detail would take a large and separate volume and require several years of research to complete.

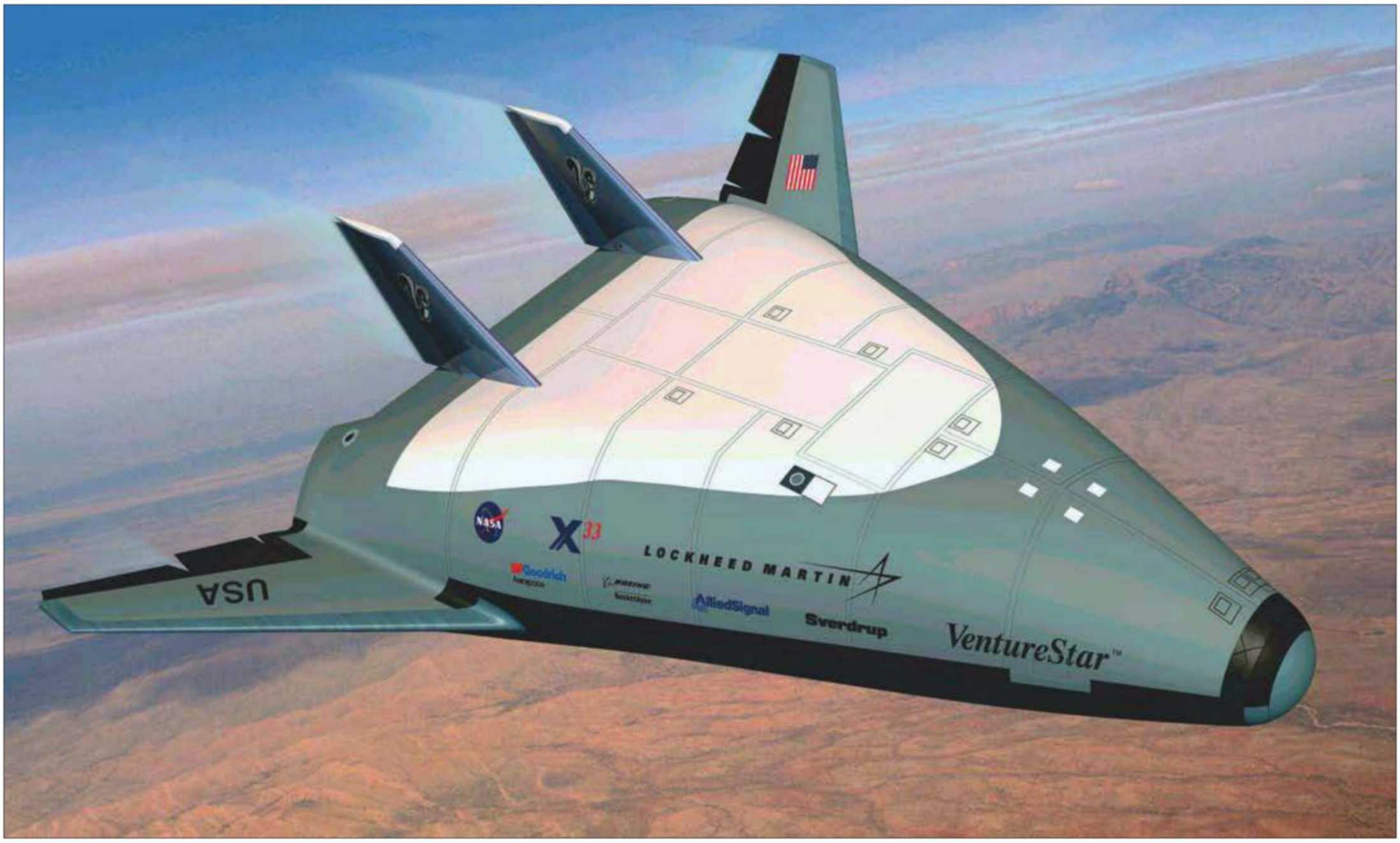
Not surprisingly there are omissions and gaps in my research for this book. Some areas of interest have proved completely inaccessible and a number of formal requests to study official documents held in various locations have come to nothing. Although many of the concepts and proposals covered here have proved too costly or technically challenging to develop or build, it is always interesting to catch a glimpse of unorthodox, bold or innovative ideas.

Bill Rose, Norfolk 2008.

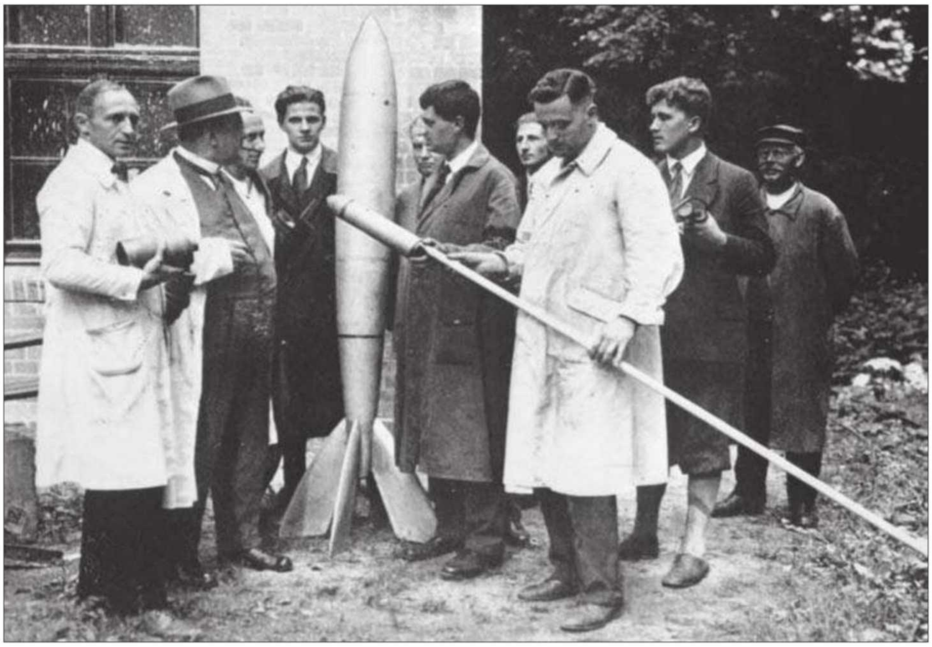
Acknowledgements

I would like to thank the following individuals for their assistance: Tony Buttler, Chris Gibson, Russell Strong, Alex Kozlov, Sergei Novikov, John Scott-Scott, David Grossman, Pete Clukey and Joel Carpenter.

Below: **The Lockheed VentureStar was conceived as a single-stage-to-orbit (SSTO) space vehicle capable of replacing the Shuttle. Lockheed promised to deliver the smaller X-33 prototype in record time, which suggested the company was drawing on work already undertaken in the black domain.** NASA



German Wartime Ambitions



Left: **This picture was taken shortly after Hermann Oberth's successful 'Kegelduese' (cone-nozzle) rocket engine test in the grounds of the Chemisch-Technische Institute on 5th August 1930. Some of the VfR members present were (from left to right) Rudolf Nedel, Dr Franz Hermann Karl Ritter, Hans Bermüller, Kurt Heinisch, Unknown, Hermann Oberth, Unknown, Klaus Riedel (holding a model of Mirak 1), Wernher von Braun (holding the Kegelduese) and an Institute employee. The almost complete Oberth/UFA rocket can be seen in the centre of the photograph.** NASA

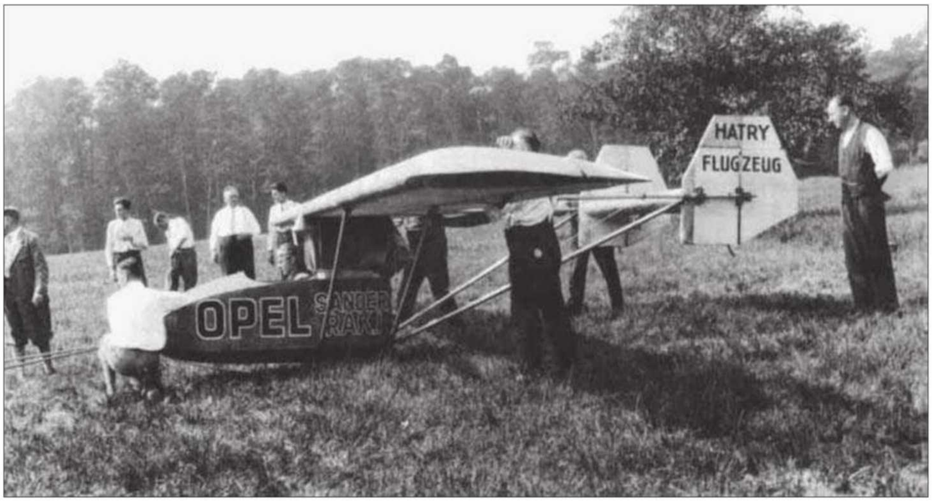
Below left: **Fritz von Opel prepares to fly a rocket-powered glider at Rebstock near Frankfurt on 30th September 1929. Sixteen small solid fuel rockets were used for this successful attempt and the vehicle was airborne for approximately 7.5 seconds.** Bill Rose

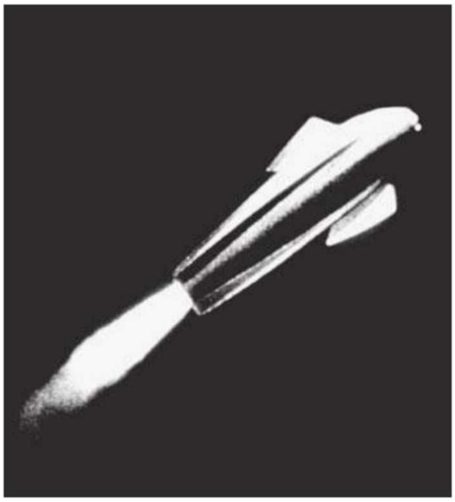
Below right: **A fictional spaceship from the prewar German science fiction film *Weltraumschiff 1 Startet* (Spaceship 1 Launches), which was shown in German occupied territories during the Second World War.** Bill Rose

Modern spaceflight began with a group of pre-war German rocket enthusiasts who created the Verein für Raumschiffahrt or VfR (Society for Spaceflight). This association was founded in Breslau on 5th July 1927 by Johannes Winkler (1897-1947), who was an engineer working for Junkers Aircraft. Winkler would become the first person in Europe to launch a liquid-fuelled rocket, called the HW-1, on 14th March 1931.

As the VfR expanded it brought together a number of talented individuals. The Society produced a journal called *Die Rakete* (The Rocket) and by the early 1930s membership stood at several hundred. Members of the VfR were surprising successful with their various endeavours to promote rocketry and spaceflight. This included involvement with the making of Fritz Lang's sci-fi film *Frau im Mond* (Woman in the Moon) and publicity stunts such as Fritz von Opel's rocket-powered car. In 1930 the VfR managed to acquire an area of land at Berlin-Tegel, which society members dubbed the Raketenflugplatz or Rocket Airfield. An assortment of model rockets was launched from this site with some of the most ambitious designs reaching altitudes in excess of 3,300ft (1km).

In 1932 the cash strapped society turned to the German Army for financial assistance and



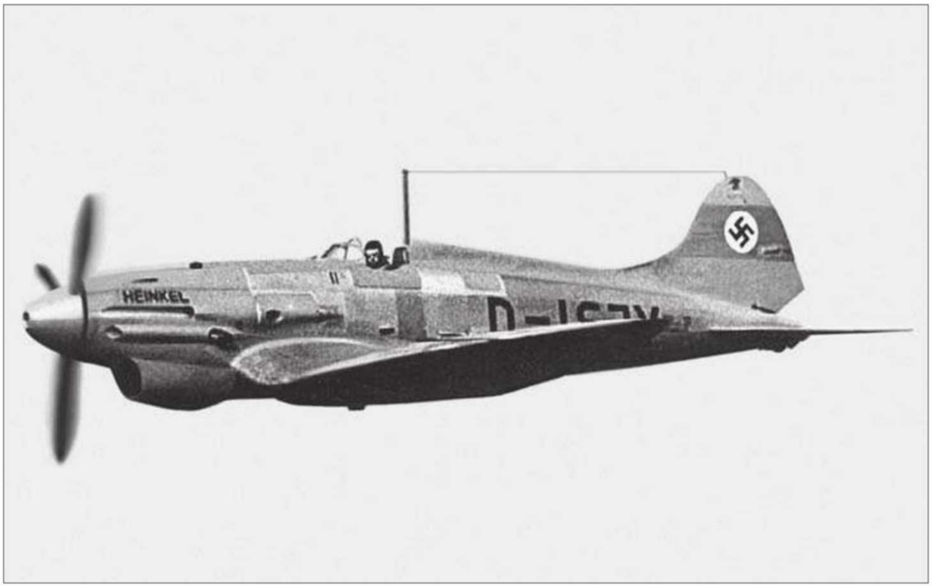


a launch demonstration was set up for Hauptmann (Captain) Walter Dornberger (1895-1980), who headed the Army's artillery and rocket research programme. Although things did not go as planned and the society's rocket failed to work, Dornberger was sufficiently impressed with what he saw to fund further development of their best ideas, providing the work focused on military applications and was undertaken in secret. VfR members eventually rejected the idea of being bound by military rules and their problems were compounded by growing protests from city officials about the group's experiments, mainly on the grounds of public safety. The Gestapo was soon applying pressure as well and the society disbanded at the start of 1933.

One member of the VfR was a young man called Wernher Magnus Maximilian Freiherr von Braun, who had been born in Wirsitz in the Province of Posen. After this area became part of Poland in 1920, his family moved to Berlin. Von Braun's interest in space and rocketry went back to a very early age and one of the books that helped to shape his thinking was Hermann Oberth's highly influential *Die Rakete zu den Planetenreumen* (The Rocket into Interplanetary Space). Having enrolled as a full-time student at the Berlin Institute of Technology, von Braun joined the VfR in 1930, where he was able to fulfil his first ambition by assisting Oberth with the testing of liquid-fuelled rocket engines.

As an exceptionally bright student von Braun continued his studies at the Technical University of Berlin, achieving a doctorate in physics on 27th July 1934. Throughout this period von Braun continued to undertake experiments for Hauptmann Dornberger and, when he left university, Dornberger offered him a research grant to work full-time for the Army at their Kummersdorf test site. Working with a small team of assistants, von Braun had by the end of 1934 launched two rockets that reached altitudes of 7,200ft (2.2km) and 11,500ft (3.5km) respectively. As rocket development progressed in a promising direction the Army began to look for a bigger test site, and it was apparently von Braun's mother who suggested that they might consider an area near the village of Peenemünde in northern Germany on the Baltic Sea; this was where her father had sometimes gone to hunt ducks.

The proposal proved popular with everyone and within months Dornberger had been appointed as the military commander of the Peenemünde test site, with von Braun being officially appointed as technical director in 1937. The creation of a rocket for use as a



Top left: **Willy Ley was a German born science writer who did much to popularise rocketry and space exploration between the wars.** NASA

Top centre: **General Walter Dornberger, who was appointed senior officer in charge of the wartime Peenemünde Test Centre.** Bill Rose

Top right: **Wernher von Braun in his office at Peenemünde.** Bill Rose

Right: **In 1937, static trials were undertaken with several small liquid fuel rocket motors designed by von Braun. It was decided to apply the technology to an aircraft and the project was fully supported by Ernst Heinkel, who provided several He 112 aircraft for flight-testing at Kummersdorf.** Bill Rose weapon progressed rapidly and the principle objective was to develop a reliable, relatively long-range ballistic missile fitted with a substantial warhead. This would eventually take the form of the A4, which is more widely known as the V-2.

Rocket Planes

By the late 1930s Peenemünde was carrying out research for the Luftwaffe (the German Air Force) and von Braun became involved with rocket propulsion for aircraft. Ground tests were conducted during early 1937 at Kummersdorf with small alcohol and oxygen rocket engines designed by von Braun himself, and static trials followed with one of the engines fitted into a Heinkel He 112 monoplane fighter. This was provided by Ernst Heinkel (1888-1958) who took a personal interest in the project. However, there were several accidents and eventually the aircraft was seriously damaged by fire. A second He 112 was supplied by Heinkel, fitted with a rocket engine and flown to a remote airfield at Neuhardenburg north-east of Berlin. In early March 1937 the He 112 was prepared for take-off by Flugkapitan Erich Warsitz (a test pilot on loan from the Rechlin Aeronautical Centre), but there was an explosion which destroyed the back of the aircraft. Miraculously, Warsitz escaped with little more than minor concussion.

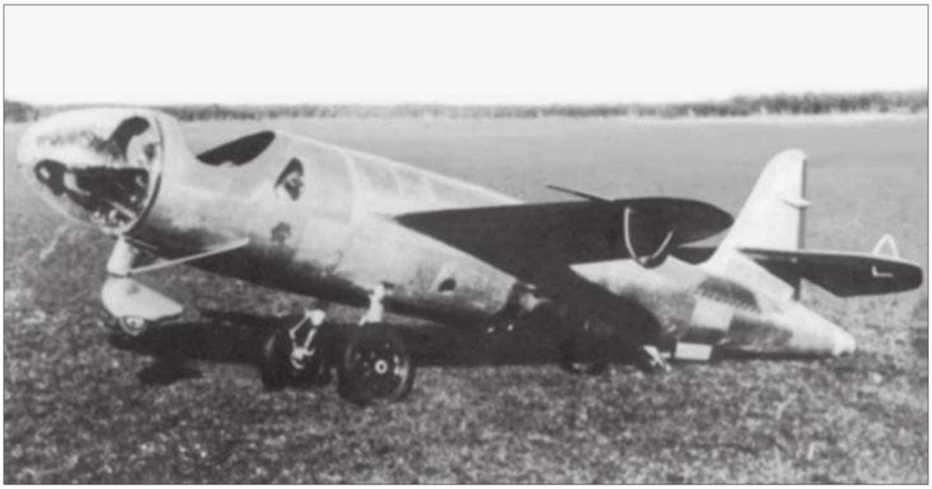
A third He 112 was equipped with a rocket engine which produced a thrust of 2,238 lb (9.95kN) for thirty seconds and was successfully flown. Used to supplement the aircraft's piston powerplant, this was found to improve the He 112's performance by as much as 33 percent. Despite one crash landing caused by engine failure the tests went well and Heinkel was sufficiently impressed with these trials to commission the construction of a small liquid fuel rocket powered research aircraft which was designated the He 176.

While tests were being conducted to use von Braun's rocket engines as a way of assisting the take-off of heavily laden Heinkel He 111 bombers, design work for the new He 176 rocketplane was beginning at Heinkel Aircraft's main facility at Marienehe, Rostock, under the direction of Hans Regner. The plans were completed relatively quickly and Walter Künzel was appointed as project manager. A small team of engineers was assembled to build the new aircraft, the first example of which was designated He 176 V1 (Versuchs = Experimental or Version One), in a hangar well away from the main facility. From the outset this project was shrouded in secrecy since the He 176 was regarded as the probable precursor to a high-speed, high-altitude research aircraft offering considerable military potential.

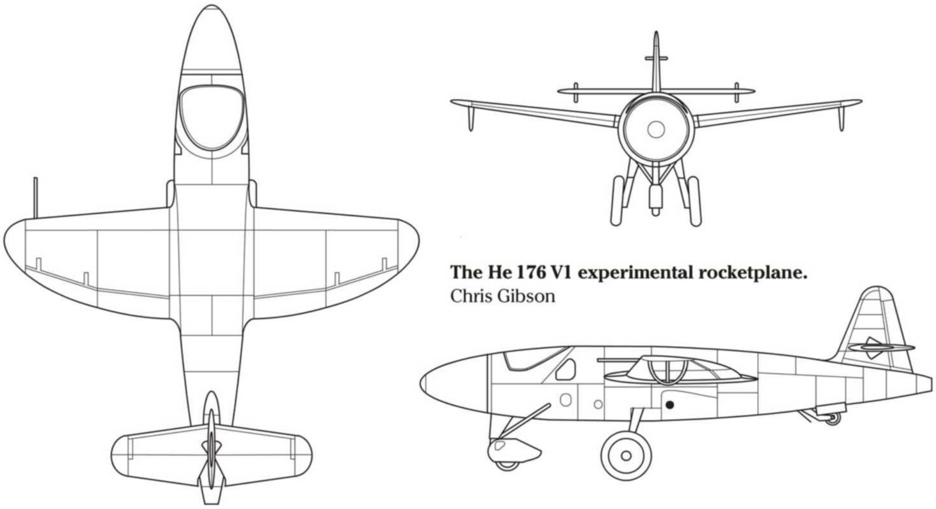
The rocket engine designed by von Braun proved too large for the He 176 V1 and concerns about reliability and control led to the substitution of a Walter R1 engine which provided a maximum thrust of 1,323 lb (5.88kN). He 176 V1 was 16ft 5in (5m) in length, it had a wingspan of 13ft 1in (4m) and a wing area of 53.8ft^2 (5m^2). Empty weight was 3,455 lb (1,570kg) and the gross weight was estimated to be 4,400 lb (2,000kg). The anticipated maximum speed with the Walter rocket engine was 435mph (700km/h) at sea level.

After its completion in early 1938 the prototype was moved to the large wind tunnel at Göttingen for testing, and then on to Peenemünde where flight trials could begin in secret. After initial taxying runs a few very short powered lift-offs were attempted in March 1939 with the aircraft carrying a minimal amount of fuel. The exact date of the first full flight of this aircraft remains unclear, but some sources claim this had been achieved on, or by, the 14th April 1939. Officially, the first flight took place on 20th June when He 176 V1 was piloted by Erich Warsitz. The following day, a group of senior Reichsluftfahrtsministerium (RLM – Air Ministry) officials, headed by Ernst Udet and Erhard Milch, attended a second test flight, but Udet found the demonstration unnerving and ordered the project to be suspended. Frantic negotiations followed and the ban was finally lifted, along with an agreement that the aircraft would be flown for Adolf Hitler, Hermann Goering and other members of the Nazi leadership at Roggentheim Airfield on 3rd July.

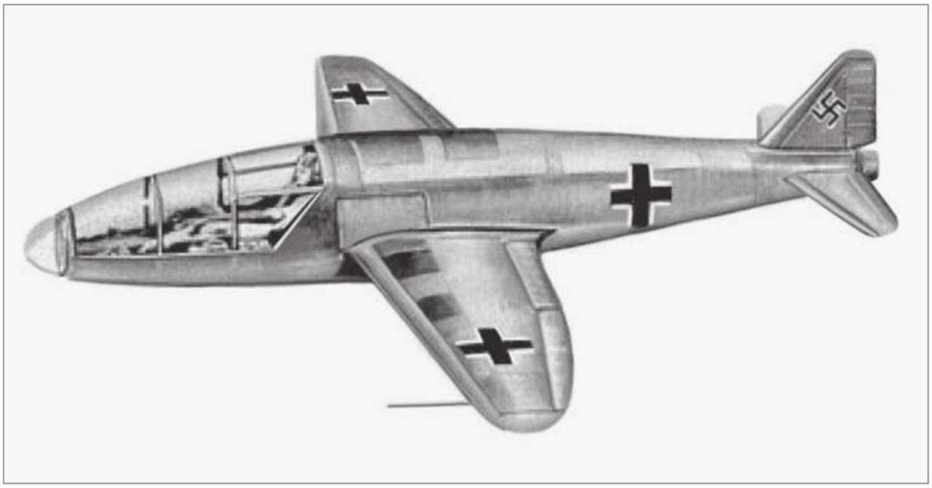
This restrained demonstration appears to have created a lukewarm response and the project was formally terminated by the RLM on 12th September 1939. It is believed that a few more test flights took place at Marienehe and then the aircraft was partly dismantled



The Heinkel He 176 V1 rocketplane was secretly built at Marienehe under the direction of Hans Regner. Bill Rose



The He 176 V1 experimental rocketplane. Chris Gibson

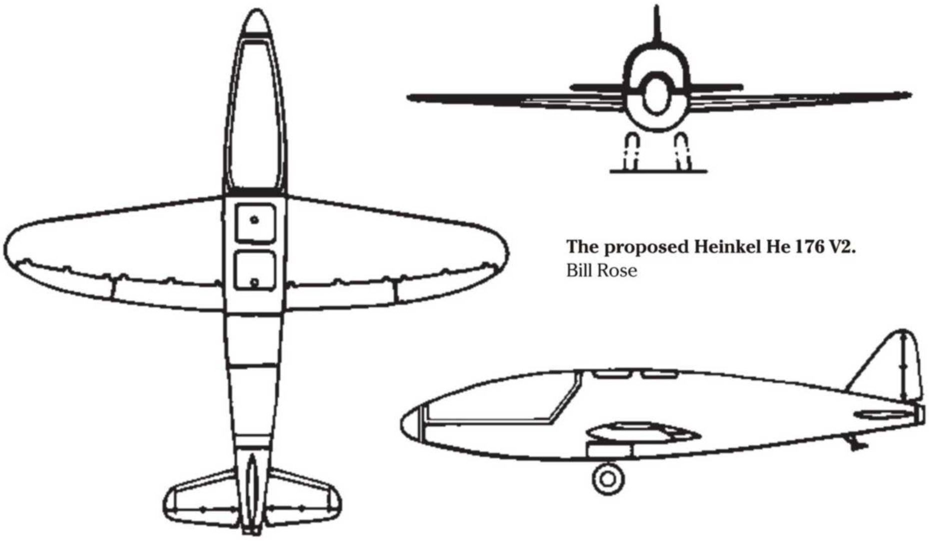


Artwork showing the proposed Heinkel He 176 V2. This aircraft was never built, although it is often confused with the He 176 V1. Bill Rose

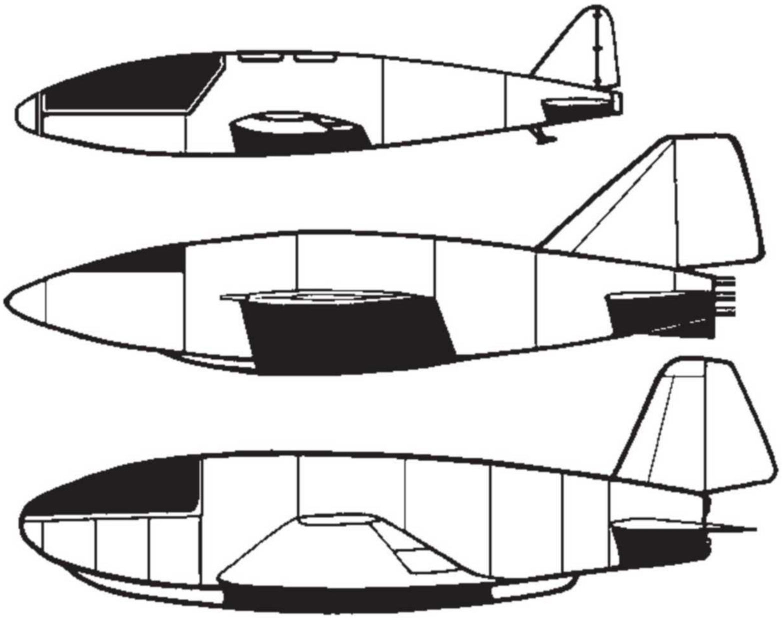
and crated up. At some point, probably a couple of years later, He 176 V1 passed into the hands of the Air Museum in Berlin, but it finally met with total destruction during an air raid over the city in 1944.

Although Heinkel hoped to build a more advanced He 176, designated V2, this new aircraft never progressed beyond a few plans and drawings. However, von Braun had already taken the concept a stage further by designing a vertical take-off (VTO) rocket powered interceptor, which he submitted to the RLM on 6th July 1939. This aircraft was somewhat similar to the He 176 V2 but it used a much higher performance rocket engine and was to be launched vertically like a rocket. Aside from that, the similarities between both concepts would suggest a considerable exchange of ideas and a degree of mutual co-operation. Wind tunnel models of von Braun's design were tested and further development of the rocket engine is believed to have been undertaken by Dr Helmut von Zborowski (1905-1969) at the BMW Bramo facility in Berlin-Spandau.

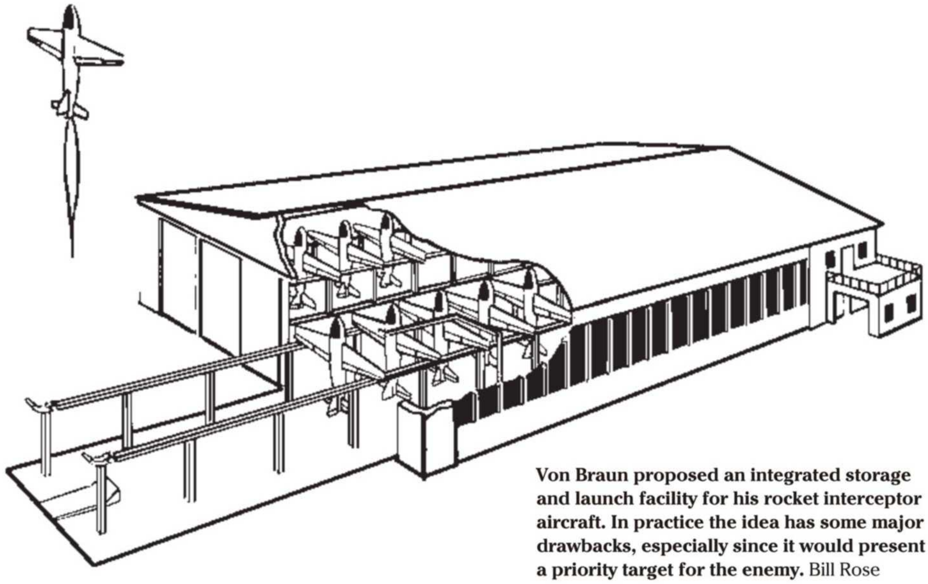
The initial von Braun rocket interceptor design showed an aircraft somewhat larger than the He 176 V1 with an overall length of 28ft (8.5m) and a wingspan of 30ft (9.15m). It had a gross weight of about 11,200 lb (5,080kg) and was powered by a liquid fuel rocket engine with an estimated take-off thrust of 22,400 lb (99.6kN). This was expected to provide a very impressive rate of climb, calculated at fifty seconds to 25,000ft (7,620m), and this anticipated level of performance led von Braun to believe that the pilot might have to throttle back to avoid encountering the 'Sound Barrier'. Once the aircraft had achieved its cruising altitude, a second 1,700 lb (7.56kN) thrust chamber would be ignited to permit a speed of 430mph (692km/h) to be maintained at altitudes up to 35,000ft (10,668m). Endurance was estimated at about fifteen minutes and, when the mission had been completed, the interceptor would return to base to make a glide landing on a retractable skid. The aircraft was to be armed with four machine guns and the pilot would receive his target information from the ground (with, in due course, assistance from radar).



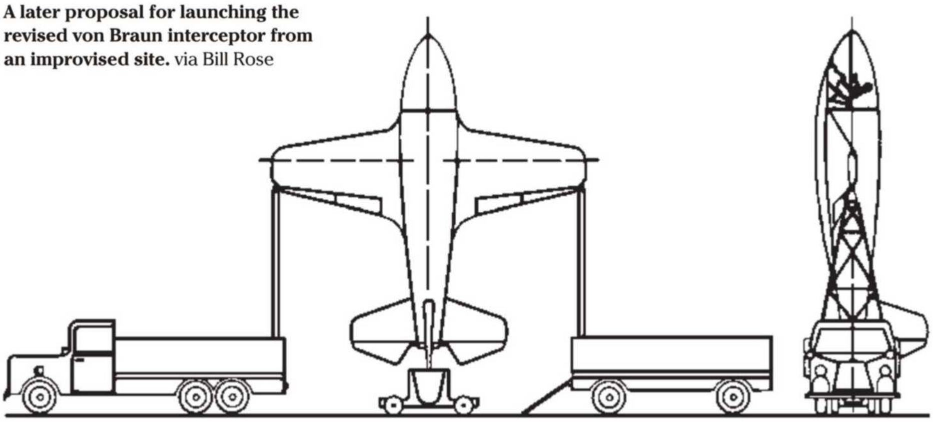
The proposed Heinkel He 176 V2. Bill Rose



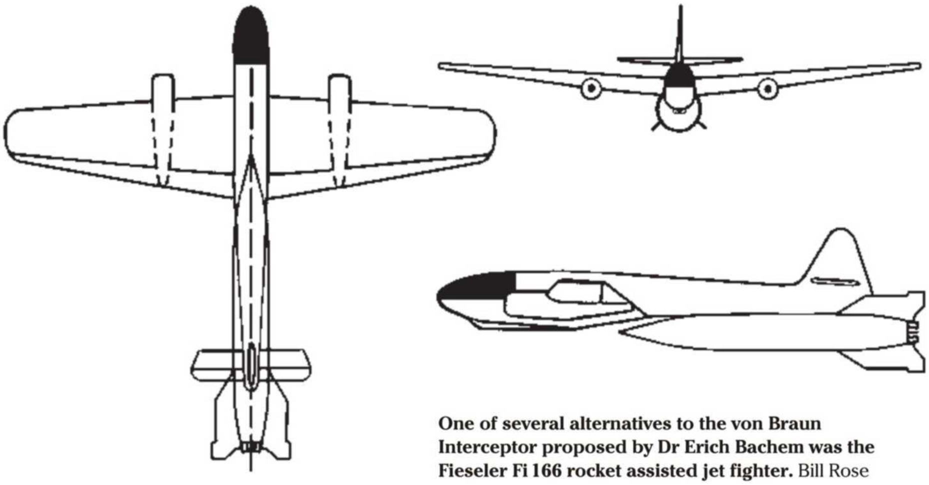
The upper design shows the Heinkel He 176 V2, the centre drawing is the initial von Braun Interceptor and the lower image depicts the revised von Braun Interceptor. Drawings are approximately to scale. Bill Rose



Von Braun proposed an integrated storage and launch facility for his rocket interceptor aircraft. In practice the idea has some major drawbacks, especially since it would present a priority target for the enemy. Bill Rose



A later proposal for launching the revised von Braun interceptor from an improvised site. via Bill Rose



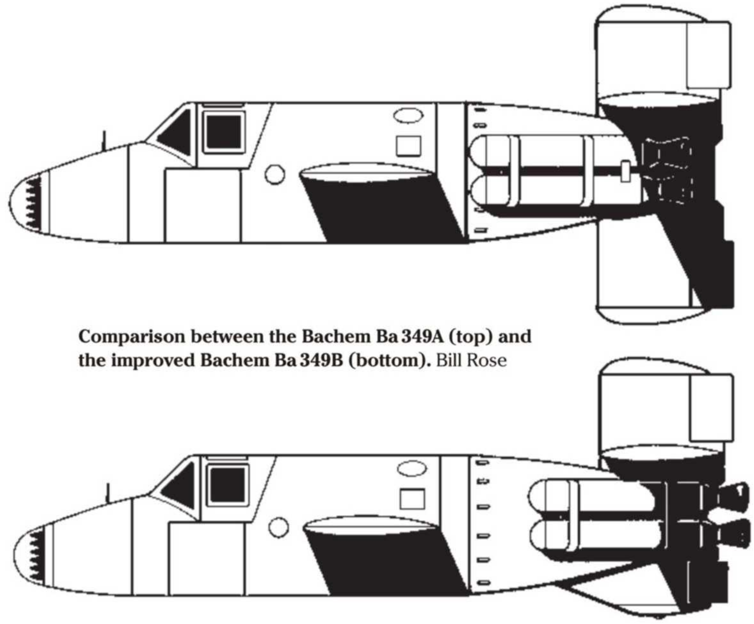
One of several alternatives to the von Braun Interceptor proposed by Dr Erich Bachem was the Fieseler Fi 166 rocket assisted jet fighter. Bill Rose

It was intended to house these aircraft in a hangar-launch facility, which was an interesting idea but somewhat unrealistic because it would have presented the enemy with a single high-priority target. Although the He 176 V1 had been cancelled by the RLM, Ernst Heinkel expressed a strong interest in developing von Braun's proposals and Dr Motzfeld carried out a full evaluation for the company. He concluding that von Braun's concept was sound but the aircraft needed to attain higher altitudes and show improvements in endurance to keep ahead of expected foreign developments. A number of improvements were made to the design and it was suggested that this aircraft could be launched from the back of a truck at an improvised site. These proposals were submitted to the RLM on 27th May 1941, but were rejected because there was no existing requirement for a VTO interceptor and the rocket powered Messerschmitt Me 163B was already on order for the Luftwaffe. However, interest in the concept persisted and further studies were undertaken by Gerhard Fieseler Werke, who was responsible for the development of the Fi 103 flying bomb at Peenemünde.

Fieseler's technical director, Dr Erich Bachem (1906-1960), produced two different proposals based on von Braun's ideas and these were given the single company designation Fi 166. Bachem's first design differed considerably from the von Braun VTO interceptor and took the form of a two-stage system. It consisted of a modified vertically launched A5 rocket that would carry an aircraft derived from a Messerschmitt Bf 109 airframe which was equipped with two wing mounted Junkers Jumo 004 turbojet engines. After launch the two-stage vehicle would climb rapidly to a height of about 39,500ft (12,000m) and then separate. The aircraft was now reliant on its jet engines while the spent A5 booster would descend by parachute and could be recovered and re-used. The aircraft's take-off weight was estimated to be 22,000 lb (10,000kg) and its maximum speed 515mph (830km/h); endurance was calculated to be approximately forty-five minutes.

The second version of the Fi 166 was closer to von Braun's final design but slightly larger with room for a two-man crew. Powered by a single high performance rocket engine, the aircraft had a lift-off weight of 13,000 lb (5,930kg), a maximum speed of 515mph (830km/h) and again an endurance of forty-five minutes.

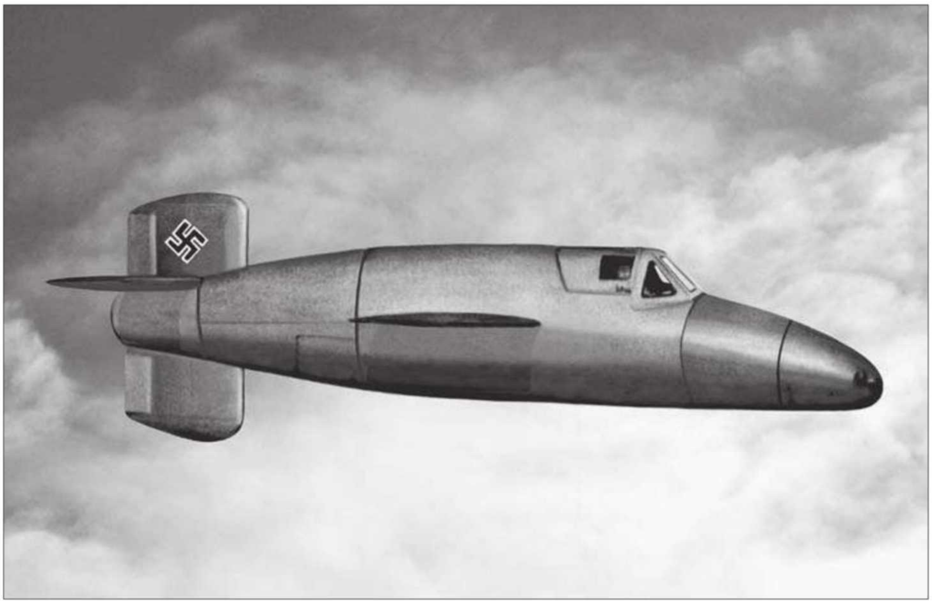
In the end these revised plans failed to generate any more interest within the RLM and von Braun's VTO rocket interceptor was shelved. Although von Braun was primarily involved with the development of ballistic missiles for the German Army, the idea of a manned rocket vehicle never went away and would eventually lead to proposals for a piloted V-2 rocket. Nonetheless, as the war began to go badly for Germany, air defence became increasingly important and the RLM issued a requirement for a lower cost alternative to the Me 163B rocket fighter. A brief design contest followed and the RLM chose the Heinkel P.1077 'Julia' over a rival proposal from Junkers known as the EF 127 'Walli'. The P.1077 was soon in development by Heinkel, but this didn't stop Dr Eric Bachem from submitting a new proposal to the RLM which drew heavily on his earlier research for the Fi 166 interceptor. Bachem had left Fieseler in early 1942 to set up Bachem Werke, a company that manufactured spares and components for fighter aircraft, but he retained close personal links with von Braun and continued to develop the rocketplane proposal, with the latter's assistance.



Comparison between the Bachem Ba 349A (top) and the improved Bachem Ba 349B (bottom). Bill Rose

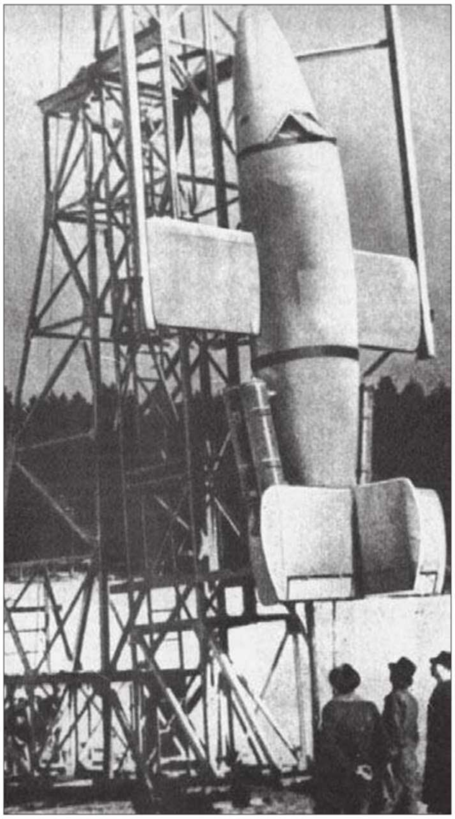
A smaller, lighter aircraft was now envisaged that used solid fuel booster rockets which would be jettisoned once the aircraft gained sufficient altitude. This resulted in the Bachem BP 20, which was a semi-expendable, low-cost combat aircraft that would be much easier to build than the Heinkel P.1077 and could be deployed at improvised sites near key targets. Using an automated launch procedure and radio guidance, the BP 20 would be fairly simple for a relatively inexperienced pilot to fly – in fact it was little more than a manned anti-aircraft missile. Both the P.1077 and Junkers EF 127 were designed to use the Walter 109-509 rocket engine and the BP 20 would utilise the same liquid fuel propulsion system. Its mission would only last a matter of minutes and, having launched an attack against an enemy bomber, the pilot would then bale out. Heinkel continued to work on the P.1077 but his company had effectively lost out to Bachem's alternative project. Bachem had somehow managed to secure the support of Heinrich Himmler, who immediately ordered that the BP 20 should have preference, and nobody argued with Himmler who headed the dreaded SS. Himmler requested the construction of 150 interceptors, to be paid for from SS funds, and this was followed by an additional order from the Luftwaffe for another fifty aircraft.

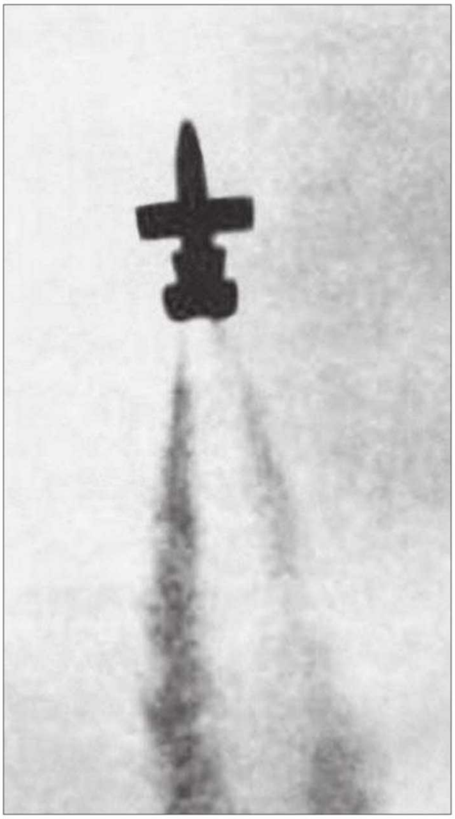
Bachem's vertically launched Ba 349A Natter (Adder), as the initial project was eventually designated, was 18ft 9in (5.7m) long, it had a wingspan of 11ft 10in (3.60m), wing area 29.6ft^2 (2.75m^2) and a height of 7ft 4in (2.25m). Natter weighed 2,415 lb (1,095kg) empty and 4,800 lb (2,200kg) fully loaded. Power would be provided by a 3,750 lb (16.6kN) thrust Walter HWK 109-509A rocket engine, supplemented by four strap-on Schmidding 553 boosters giving an additional 1,000 lb (4.4kN) of thrust each.



During November 1944 gliding trials of ballasted Ba 349A Natters began near Heuberg using a Heinkel He 111 as the tow aircraft. Simulation by Bill Rose

Throughout this period, von Braun provided unofficial assistance to the project and helped with engineering development at Peenemünde. Wind tunnel testing of Natter models to Mach 0.95 took place at Braunschweig and the first pre-production airframes were constructed at Bachem's Waldsee factory in the Black Forest, with several small local workshops being earmarked to manufacture parts when production increased. Almost every part of the airframe was built from wooden components bonded together with glue, making manufacture a relatively easy and low-cost undertaking. Reducing the aircraft's overall complexity to a minimum was essential and the Natter's control surfaces were limited to just cruciform tailfins. It was calculated that each complete aircraft would take approximately one thousand man-hours of labour, although on several occasions Bachem talked about six hundred man-hours with most of the





Far left: **Based on research for the Fi 166 and von Braun Interceptor, the vertically launched Bachem Ba 349A interceptor was rushed into operational service during the last few days of World War Two, but never saw combat. This photograph shows an unmanned test example being prepared for the first vertical launch on 22nd December 1944.** Bill Rose

Left: **Vertically launched test flight of a Bachem Natter in early 1945.** Bill Rose

construction and assembly being undertaken by unskilled labour using basic hand tools in small facilities.

After launch the Natter would rapidly ascend to intercept enemy Allied bombers and its rate of climb was a very impressive 30,000ft (9,144m) per minute, with a ceiling of 52,000ft (15,849m). The maximum speed reached during testing was 560mph (900km/h) and the range of this point defence interceptor was 37 miles (59km). Having visually sighting the enemy target the pilot would attack by firing a salvo of twenty-four Föhn (Storm) 73mm unguided air-to-air rockets, or alternatively thirty-three R4M 55mm folding fin rockets; these were contained in the nose section. With his fuel exhausted the pilot would then bale out and the engine section would descend by parachute to be recovered by a ground crew. The entire mission would be completed in a matter of minutes. Although the wooden airframe was disposable, it was hoped that the valuable Walter rocket engine could be re-used.

The first Natter test flight took place on 14th December 1944 at Neuberg on the Danube when the third prototype, with its major components replaced by ballast, was towed behind a Heinkel He 111 to an altitude of 18,000ft (5,500m) and released. It performed well as a glider, test pilot Flugkapitan Zeuber described the aircraft's control as excellent and he found that the escape procedure worked satisfactorily. Further towed flights followed without incident and then, starting on 22nd December, eleven unmanned launches were made using the solid fuel booster rockets.

Considerable pressure was now being applied by the SS to have Bachem's Natter in service as quickly as possible, while the RLM anticipated the imminent deployment of high-altitude USAAF Boeing B-29 bombers to Europe. This concern arose after the USAAF flew an early production B-29 to England in March 1944 and demonstrated it to 8th Air Force staff. The aircraft had actually been on its way to Calcutta, but US Intelligence wanted the Germans to believe they would soon be facing these new bombers and it is evident that the message got through. Development of the Natter progressed well until the first manned, powered flight was undertaken in late February 1945. Soon after the vertical launch, Bachem's test pilot Lothar Siebert was killed when a faulty cockpit canopy became detached. Despite this initial setback, six or seven further manned test launches took place, all of them proving successful. As a result, in April 1945 ten production Ba 349A Natters were hastily set up at Kircheim on Teck to intercept Allied daylight bombers. As the young Luftwaffe pilots waited for orders to launch, American ground forces came within range of the site and the crews were forced to destroy the aircraft, thus preventing them from falling into enemy hands.

By this time an improved version of the Natter called the Ba 349B was entering production. The aircraft featured a greater rate of climb, a higher top speed of 630mph (1,013km/h) and extended endurance. It was also proposed that two 30mm MK 108 cannons might be fitted to supplement the twenty-four Foehn 73mm unguided air-to-air rockets. When the war ended a total of three Ba 349B aircraft had been built and one test-flight had been made. An almost unknown final development of the Natter, designated Ba 349C, was intended for rail launching from the back of a truck or possibly the deck of a ship, but this proposal never progressed beyond a study. In operation, the Ba 349C would have been very similar to the second version of von Braun's proposal.

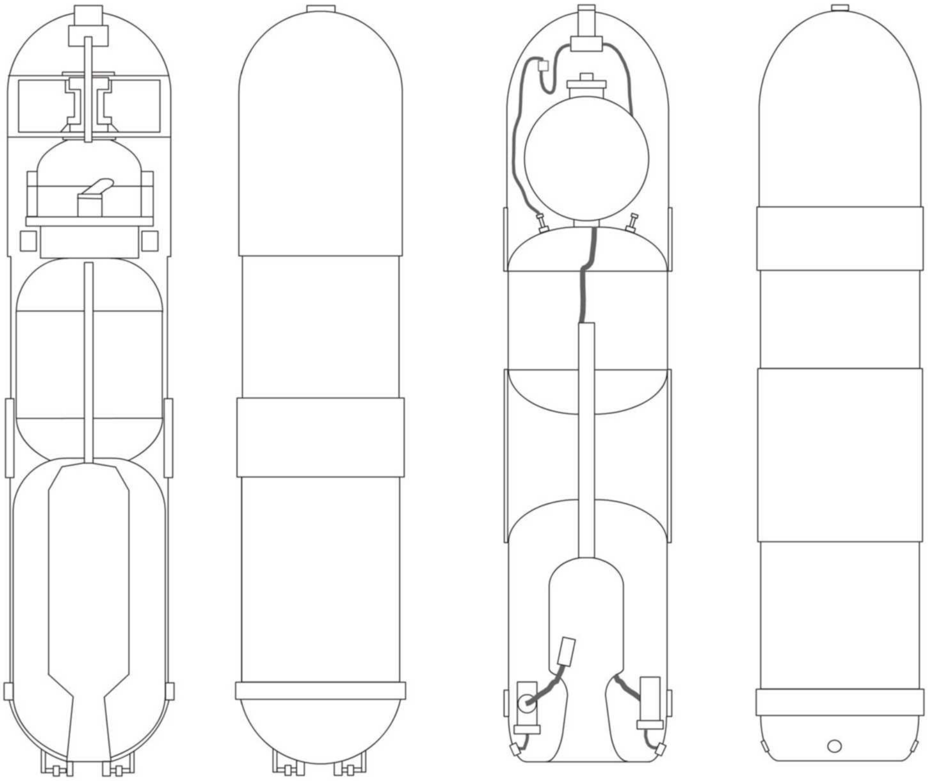
An unconfirmed report surfaced during the mid-1990s which suggested that, during a semi-operational test flight in April 1945, a Ba 349A engaged and shot down an American B-24 bomber. However, to date no evidence has been found to support this claim and it appears to be completely bogus. Plans for the Natter were sold to the Japanese, who managed to assemble a couple of examples before hostilities ended but never conducted a test flight. It is possible that at some point during the Second World War von Braun considered the idea of launching a small rocket-powered aircraft to a very high altitude with an A4 booster. A single drawing of a swept-wing, rocket-powered aircraft intended for a V-2 (A4) launch was found at the Boeing Historical Archives and it may have been inspired by a wartime study.

Towards a Strategic Weapon

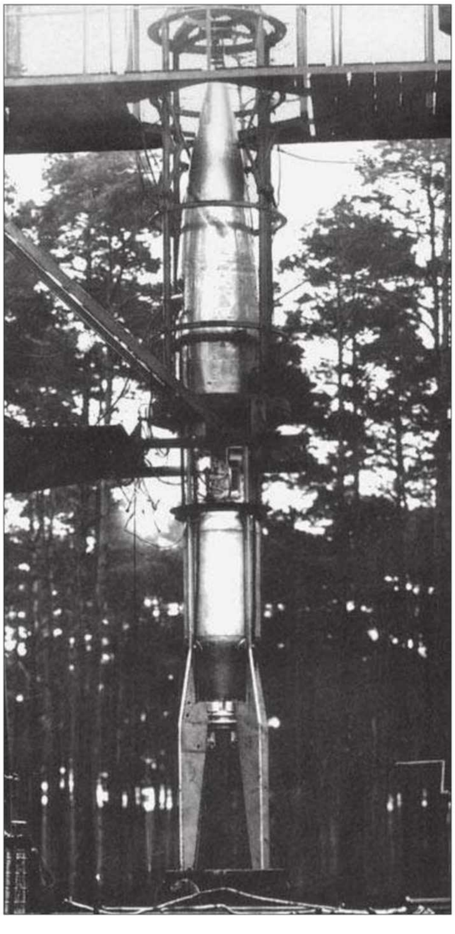
In the overall scheme of things rocket-powered aircraft were something of a distraction for Wernher von Braun, who is chiefly remembered for designing the wartime V-2 rocket and the Saturn V rocket for NASA's Apollo Moon Project. Before he started working for the Army in an official capacity, von Braun was being funded by the military to develop the first in a line of liquid-fuelled rockets that were designated the Aggregat (Aggregate) series. The first of these designs, called the A1, was a torpedo-shaped rocket. It measured 4ft 8in (1.4m) in length, was 11.8in (300mm) in diameter and had a launch weight of 330 lb (150kg). The liquid fuel engine designed by Arthur Rudolph used alcohol and liquid oxygen and produced 662 lb (2.94kN) of thrust while burning for sixteen seconds. However, all did not go as planned and the rocket exploded on the launch pad.

A second design called the A2 followed and two examples were built. This rocket was essentially an improved version of the A1, with the gyroscope unit moved to the centre of the rocket. The A2s were given the names Max and Moritz and both performed successfully when demonstrated to senior officials in December 1934. Once von Braun had become fully involved with military rocket development work began on the construction of a third more sophisticated design called the A3. It was hoped this rocket would perform successfully and could be scaled up for use as a ballistic missile, which was itself designated A4 and given a full specification in March 1936.

The larger A3 differed in appearance from earlier designs in having tailfins and a pointed nose. It had a length of 22ft (6.7m), a diameter of 2ft 3in (0.68m), a fin span of 36in (0.93m) and a gross weight of 1,630 lb (740kg). The liquid fuel engine provided a lift-off thrust of 3,305 lb (14.7kN). The first A3 test launch took place on 4th December 1937 and was followed during the next week by three further launches. In each case the rocket failed, the reasons generally being attributed to the experimental inertial guidance system.



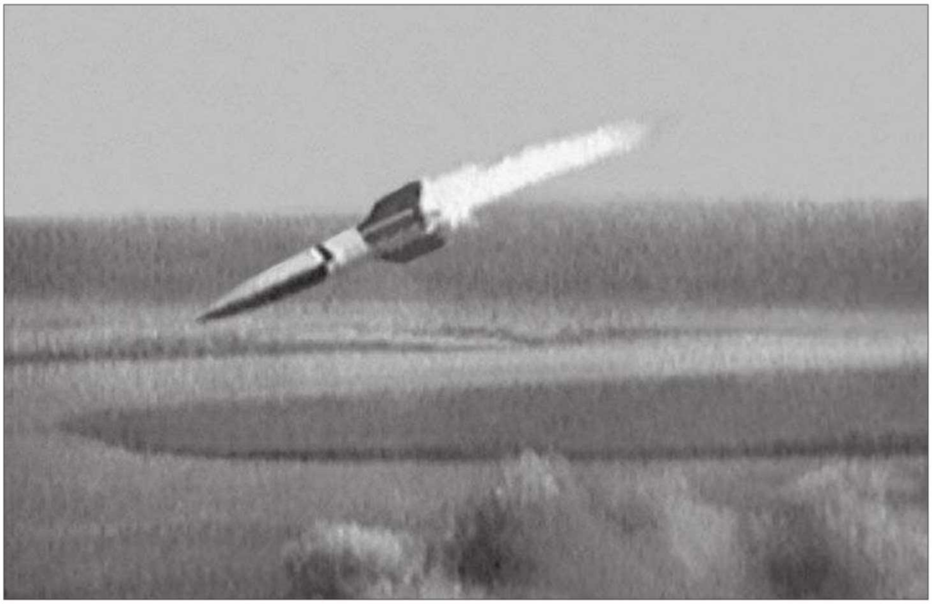
Above: **Von Braun's first experimental liquid fuel rocket, built with German Army funding (shown left). It was designated A-1 but exploded on the launch pad. The design was revised and two similar but improved A-2 rockets followed. These were given the names Max and Moritz and both performed well, paving the way for more ambitious designs.** Chris Gibson

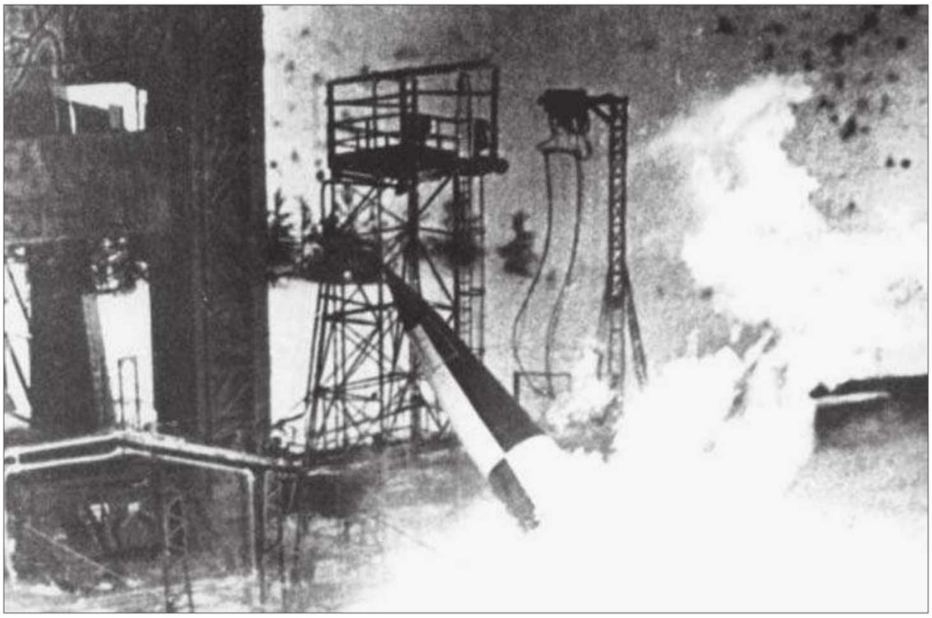


Right: **The A3 was a considerable step forward from the A2 rocket and utilised technology intended for use in a scale prototype of the planned A4.** Bill Rose

By Christmas of that year the A3 had been abandoned and a complete re-think on the rocket programme had begun. By mid-1938 von Braun and his team had designed and produced a new experimental rocket which resembled a miniature version of the future A4. This received the designation A5 and was 19ft (5.82m) long, had a core diameter of 30in (780mm), gross weight 1,980 lb (900kg) and used the same liquid fuel engine as the unsuccessful A3, with the same thrust. After wind tunnel trials and scale model drop tests, an A5 was successfully launched at Greifswalder Oie (close to the Peenemünde test site) and reached an altitude of 7 miles (12km). Although the A5 failed to exceed the speed of sound during its initial tests, this objective was eventually achieved with a high-altitude drop test. By late 1939 von Braun knew they had resolved most of the earlier technical problems and the A5 could now be scaled up in size as the A4.

Tests using A5 rockets were still ongoing when America entered the war and the final flight took place in early 1942. The A4 was now ready to succeed the A5 and the first launch was made in March 1942, but the rocket crashed a few moments after lift-off. The second example was slightly more successful, climbing to an altitude of 36,000ft (11km) before exploding. The third A4 was launched on 3rd October 1942 and performed without problems, climbing to 265,000ft (80km) before falling back to Earth 120 miles (193km) away. This performance almost qualified it to become the first man-made object to reach space. In November





Left: **In this poor quality photograph an errant A5 is captured on film a split-second before impacting into the ground.** Bill Rose

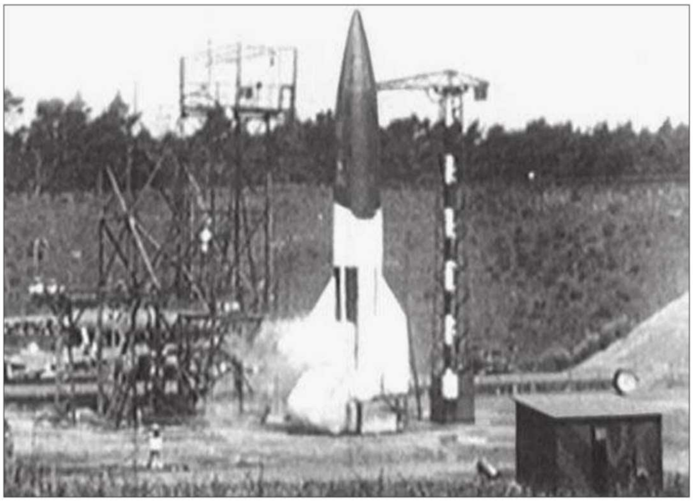
Below left: **A4 (V-2) Test vehicle No 10 explodes during launch at Test Stand V11, Peenemünde, in January 1943.** Bill Rose

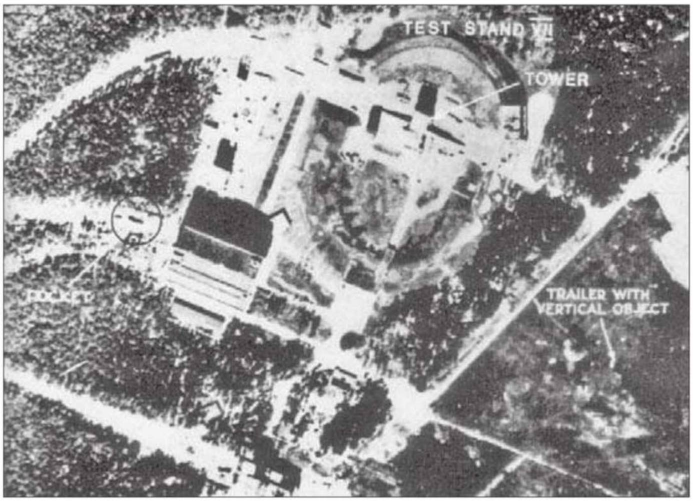
Bottom left: **The test launch of an A4, believed to be in 1943.** Bill Rose

Bottom: **Wartime RAF photo-reconnaissance image of Peenemünde showing Test Stand V11 and identifying a V-2 rocket on a trailer.** Imperial War Museum

1942 Adolf Hitler approved the A4 programme and production began in early 1943. The rocket was now renamed V-2 by Nazi Propaganda Minister Joseph Goebbels (for Vergeltungswaffe 2 or Reprisal Weapon No 2). The designation V-1 had already been assigned to the Fieseler Fi 103 flying bomb.

By now the Allies were becoming aware of the threat posed by Germany's rocket programme and the RAF launched a massive raid against the Peenemünde test site on the night of 16-17th August 1943, which involved almost five hundred bombers. Codenamed Operation *Hydra*, the RAF raid caused serious damage to the facility and killed hundreds of personnel including many skilled foreign prisoners. The casualties included rocket engine specialist Dr Walter Thiel, who died with his family after a direct hit on their air-raid shelter. After this attack some rocket testing and training was moved to Blizna in Southern Poland and it was immediately decided that rocket manufacture would continue at new secure facilities. Under the ruthless direction of SS General Hans Kammler, full-scale production of V-2 rockets was started at the hellish underground Mittelwerk complex near Nordhausen. Thousands of slave labourers worked long hours on the Mittelwerk produc-





Right: **Entrance to Tunnel A for the massive Dora underground plant at Nordhausen (also known as Mittelwerk).** US Army

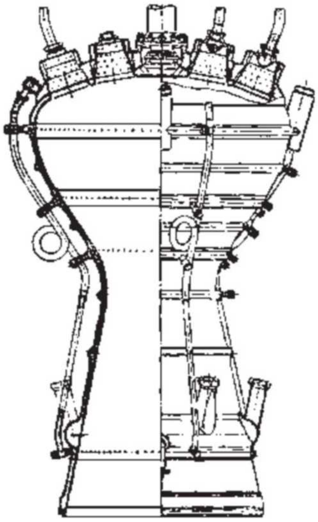
Below right: **Components for V-2 rocket engines stored within the vast Dora underground complex near Nordhausen.** US Army

tion lines and many died of exhaustion or malnutrition, or were killed in serious industrial accidents.

However there can be little doubt that Operation *Hydra* had a significant impact on Germany's rocket programme and held back the deployment of the V-weapons for several months. The A4 rocket was a fraction over 46ft (14m) in length, it had a core diameter of 5ft 5in (1,650mm), a finspan of 11ft 8in (3.55m) and a gross weight of 28,250 lb (12,814kg). A4's rocket engine was rated at 55,125 lb (245kN) thrust, it had a burn time of sixty-eight seconds and was fuelled with alcohol (B-Stoff) and liquid oxygen (A-Stoff). 8,300 lb (3,765kg) of alcohol (ethanol and water) was carried in the forward aluminium fuel tank and 10,803 lb (4,900kg) of liquid oxygen was in the second tank. A third smaller tank contained hydrogen peroxide (T-stoff) which was used to drive the turbopumps. Ignition was achieved by the use of a hypergolic mixture that burnt when mixed and the combustion chamber rapidly reached a temperature of 2,500 to 2,700°C, the fuel being circulated through the combustion chamber's cavity wall. This kept the combustion chamber's temperature at a manageable level and pre-heated the fuel, which was then pumped into the combustion chamber through 1,224 nozzles. The early rocket engines also allowed a small amount of alcohol to enter the combustion chamber directly to form an inner protective boundary layer, although this was later found to be unnecessary.

The A4 rockets were not guided weapons in the modern sense. They relied on an inertial gyroscopic control system linked to the control surfaces on the tail and four graphite vanes in the exhaust flow. Accuracy at best was patchy and the ability to place one of these rockets in the general area of a city was all that could be expected. Later on a few A4s utilised radio direction beams for guidance, although this technology remained purely experimental.

At the beginning of September 1944 a detachment known as Batterie 444 became the first operational A4 rocket unit and was set up near Houffalize in Belgium to begin attacks on Paris. At about the same time Batterie 485 prepared to launch missiles against London from a base at The Hague in the Netherlands. The first A4/V-2 fired in anger was launched by Batterie 444 against Paris on 5th September 1944, and on 7th September Batterie 485 launched the first two examples towards London (which was called Target 42); the first of these fell in Chiswick at 6.43pm. During the following months just over three thousand A4s were fired against Allied targets, most landing in Belgium or England. The last examples fired towards England were launched on 27th March 1945 and the final British civilian to be killed in a rocket attack was Mrs Ivy Millicham who lived in Orpington, Kent. About 2,750 Londoners were killed by A4 rocket attacks and at least 6,500 were injured. Many more were killed in mainland Europe by A4 hits, although in truth this weapon caused more psychological damage than actual physical harm.



Original drawing of a V-2 combustion chamber. Bill Rose

Left: **V-2 trial launching procedures at Test Stand X.** Bill Rose

Bottom left: **The grim, immediate aftermath of a V-2 impact at a road junction in Antwerp, Netherlands on 27th November 1944.** US Army

The A4 was equipped with a 2,204 lb (1,000kg) warhead containing Amatol 39A explosive and the blast was often less destructive that that caused by the V-1 flying bomb. This was due to the A4's supersonic impact into the ground but the weapon's speed on arrival also meant there was no warning of its approach; as a consequence the loss of life was statistically greater. Unnervingly, because of its supersonic velocity the A4's approach would often be heard after the impact.

The following details remain controversial. According to official US sources the Germans developed a chemical warhead for the A4. This type of warhead certainly existed for the V-1, which had the reference Fi 103D-1, but the requirements for the two weapons differed considerably and any chemical agents carried by the A4 needed to be dispersed prior to impact. The most likely content of a chemical warhead would have been the Sarin nerve agent, which was invented by Nazi scientists and manufactured in quantity. There has also been much speculation about a proposed nuclear warhead for the A4 and the idea has appeared on various Internet conspiracy sites from time to time. There are two serious problems with this suggestion. First, the Germans were some way behind the Americans in developing a nuclear bomb and secondly, the first atomic bombs were far too big and heavy to be carried by an A4. It took many years of intensive work by American and Russian scientists to make these devices small enough for use with ballistic missiles. But it is possible that a radiological warhead was considered for the A4 and this cannot be entirely dismissed, even if the idea progressed no further than a few initial plans.

It is certainly worth noting that in 1947 the Russians began the development of the R-2 'Sibling' missile, which was a stretched and improved version of the A4 with a range of 340 miles (550km). This rocket was designed to carry a radiological warhead which released a deadly cloud of dirty rain that would fall over the target area; this was similar in design to a chemical warhead. The R-2 missile entered service in the early 1950s and this rather unpleasant weapon may have been totally Russian in origin, but it is tempting to consider the possibility that it was based on a wartime German design. However, the Nazi hierarchy were fully aware of the response they would trigger by resorting to chemical, biological or radiological weapons. Such an act would have resulted in a massive and devastating British response with anthrax and various less lethal First World War chemical agents, so there would have been be no winners in a full-scale exchange of this nature.

Also under development at Peenemünde during the 1940s were several missiles related to the A4, including a small-scale winged version designated A7 for possible use by the Kriegsmarine (Navy) and the Wasserfall surface-to-air missile. There was also the A8, which was an improved and stretched A4 with storable propellants that was developed by Dr Helmut von Zborowski at BMW Bramo in Berlin-Spandau. Work on the A8 proceeded slowly and this missile never reached the hardware stage, but after the war Zborowski was recruited by the French and work resumed on the rocket. As such it became known as the 'Super V-2', but it was never built.

There was another missile called the A6, but this designation appears to have also been used more than once and included a manned A4 project, so I will return to the project in more detail shortly. Since his time with the VfR, von Braun had dreamt of space exploration and building a rocket that could leave the atmosphere. The A4 almost provided that capability but von Braun's time working for the Wehrmacht was devoted to the development of new weapons and nothing much changed after Reichsfuhrer-SS Heinrich Himmler encouraged him to join the SS in 1940. Much of the discussion about spaceflight remained limited to his immediate colleagues and von Braun later claimed that this had always been his objective, and that he regretted the attacks on Belgium and England.

In October 1943 von Braun was reported for holding a discussion with two colleagues who agreed with him that they would rather be working on the design of a spaceship. Von Braun went on to comment that war wasn't going very well. This eventually led to his arrest by the Gestapo in March 1944 and Dornberger had to enlist the help of Reichminister Albert Speer to secure his release. After two weeks in a cell at Gestapo Headquarters in Stettin, Poland, von Braun returned to his duties, although he became more careful about voicing his opinions in public places.

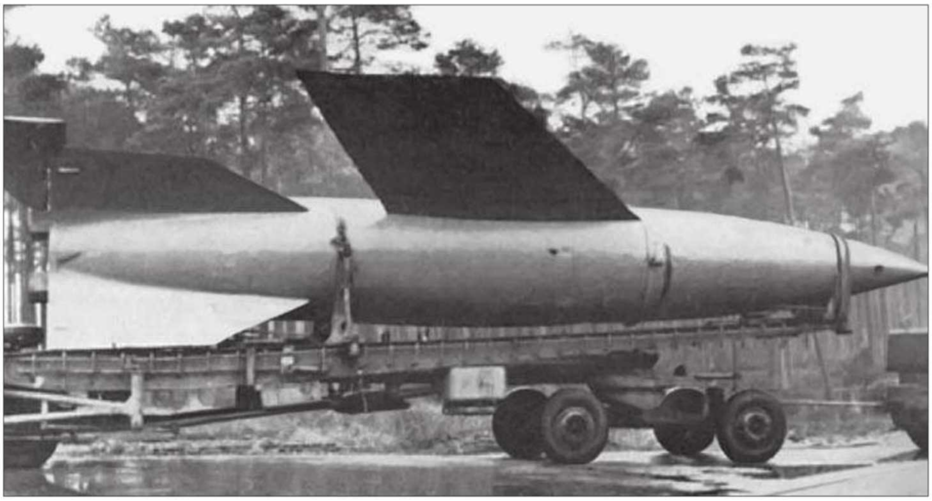
Work continued to improve the performance of the A4 while the design of its successor, the A8, had almost been completed by mid-1944. Another option to extend the range of the A4 was to fit the missile with wings and this presented the possibility of building a manned rocketplane that could undertake a controlled descent, and a manned or unmanned upper stage for a large missile with Trans-Atlantic range. Designs for a winged A4 had been under consideration since 1943 and it was hoped to double the range with a missile called the A4b. This is described shortly.

As noted, a closely related programme used the name A6, although rather confusingly this designation was also used for studies of a slightly larger improved version of the A4 that employed different propellants such as nitric acid with kerosene. The exact reason for this overlap is unknown, but von Braun may have felt it was prudent to keep certain details from the hierarchy by using complicated references. The 'real' A6 was similar to the A4b, but this A4 version was manned and would be equipped with a supplementary ramjet engine for high-altitude cruise which burnt aviation fuel or a coal slurry.

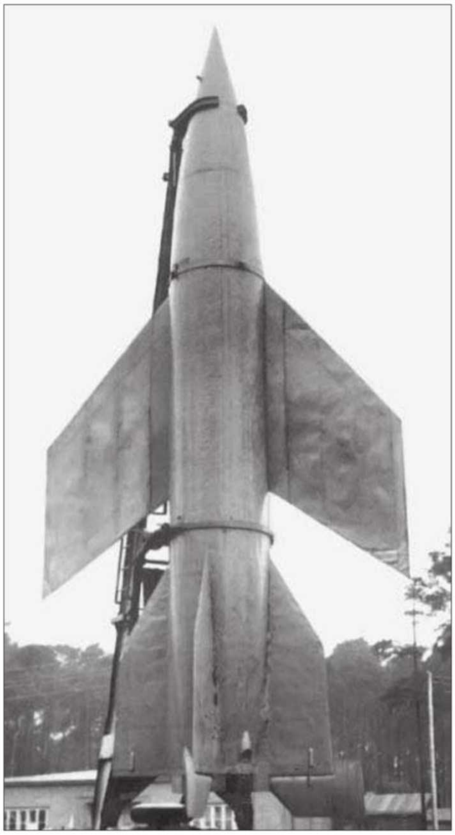
The plans for the A6 were submitted to the RLM as a re-usable high-performance photo-reconnaissance vehicle to be launched in the same way as a normal A4. Initially it was proposed that, after a vertical launch, the A6's rocket engine would lift the craft to an altitude of about 300,000ft (90km) where it would be travelling at approximately Mach 4. The A6 would then begin its descent to about 100,000ft (30km), at which point the ramjet would be ignited. This would allow the aircraft to cruise at around 1,800mph (2,900km/h) for twenty-five to thirty minutes before finally returning to base where it

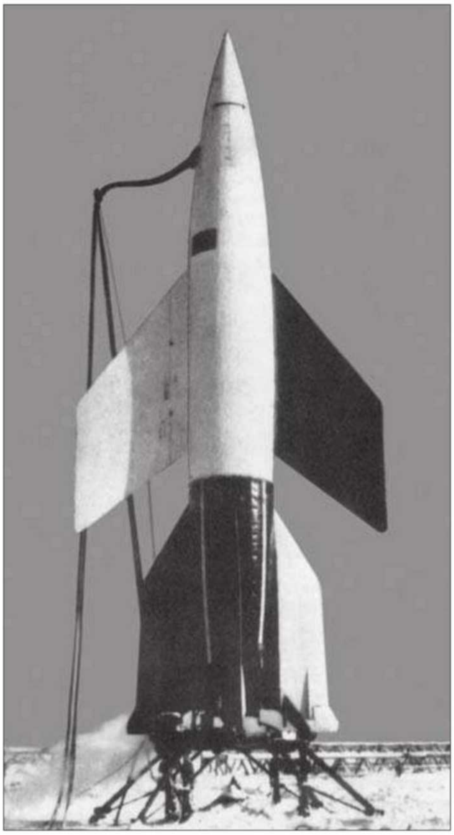
Right: **Dr Helmut von Zborowski, who headed the Advanced Propulsion Unit at BMW-Bramo in Berlin-Spandau. He was heavily involved with all aspects of wartime rocket and ramjet development.** Bill Rose

Below right: **During a Christmas banquet in 1944 Dornberger and von Braun receive a message from Hitler announcing that they are to receive awards for service to the Reich.** Bill Rose



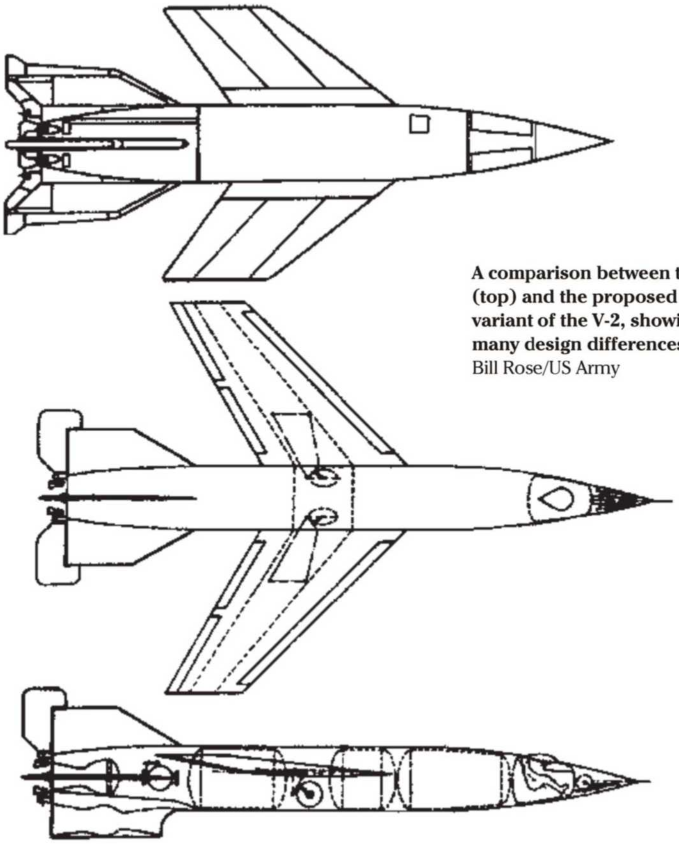
Bottom right: **The first of two A4b winged V-2s seen on a trailer at Peenemünde.** Bill Rose





The first winged A4b in unpainted condition. Note the enlarged tail fin rudders. Bill Rose

The first A4b just prior to launch at Test Stand X. Bill Rose



A comparison between the A4b (top) and the proposed manned variant of the V-2, showing the many design differences. Bill Rose/US Army

would make an un-powered runway landing. The A6 would deploy a tricycle undercarriage and the landing speed would be about 100mph (160km/h). The use of a braking parachute was also considered desirable and some discussion is thought to have taken place on the idea of using a turbojet in place of the ramjet during trials to facilitate a controlled runway landing.

A variation of the A6 design had a stretched fuselage that contained a large tank of acetylene to power the ramjet, and there were studies into using tetranitromethane and visol for the main engine to boost the vehicles range to 2,000 miles (3,218km). The A6 was designed to carry one person and the cabin would be pressurised, although the pilot would wear a full-pressure suit and an ejector seat would be fitted for emergency use.

The A6 proposal was carefully considered by the RLM, but finally rejected because there was no requirement for such an advanced design. This concept would have taken considerable effort and expense to develop and it was many years ahead of its time. That said, the A6 generated considerable interest with the Americans and Russians after the war and led to the development of the US Navaho and the Russian Burya/Buran.

The manned A6 may have been rejected, but a series of engineering studies were begun in late 1944 to again determine the viability of a winged A4, with the aim of doubling the missile's range and bringing cities like Liverpool and Glasgow within reach. Some tests had already been carried out in 1942 to establish if a supersonic wing was suitable for the A5, and this had led to the development of the A7 above. Eventually, several standard A4s were taken from the production line and fitted with wings under the new designation A4b, which was used to avoid this development being blocked by Hitler who viewed all experimental rocketry with suspicion. Other minor changes were made to the tailfins. Von Braun then decided to convert another twenty A4 missiles and the first launch was attempted on 8th January 1945, but there was a guidance failure and the rocket crashed shortly after lift-off. A second launch was made on 24th January 1945 and the rocket attained an altitude of about 50 miles (80km). It also became the first winged vehicle in history to attain supersonic speed, reaching 2,684mph (4,319km/h).

The second flight went well until the rocket began its descent and one of the wings was torn off. This represented the end of the A4b trials and it was realised immediately that the existing design was unsuitable for the intended purpose. There were plans to mount a version of the A4b known as the A9 on top of a bigger booster called the A10, and other versions were proposed. The first was very similar to the A4b while another was an adapted version of the manned A6. However, an A9 variant using an arrow-shaped wing configuration had been under consideration since 1941 for the upper stage of a big A9/10 Intercontinental Ballistic Missile (ICBM) and, if history had taken a different course, this design might have also been used to carry a German astronaut to the edge of space. As far back as 1939 Dornberger had indicated that he expected to see the development of a rocket capable of reaching America and preliminary drawings of the A9/10 were completed in 1941. These showed the upper stage largely shrouded in the fuselage of the main rocket, which resembled a scaled-up A4.

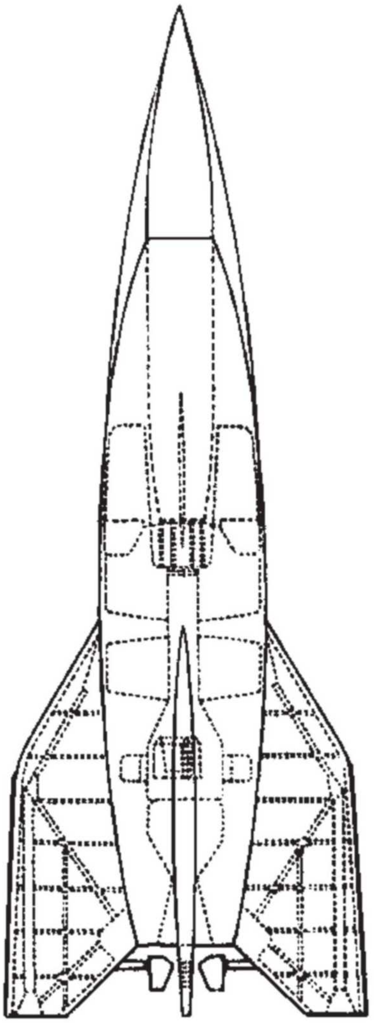
The specifications for the A9/10 combination underwent several revisions and the overall length of later versions measured approximately 112ft (34m) with a core diameter of 13ft 6in (4.11m). The rocket was estimated to have a lift-off weight of approximately 100 tons (90.7 tonnes) and the single engine used in the first stage would have a thrust of 224 tons (2,000kN), which would propel the rocket to an altitude of 34 miles (55km) and a speed of 2,684mph (4,319km/h). After separation, the A10 booster would return to Earth and it was hoped that parachutes would permit a soft landing and make its re-use a possibility. The A9 upper stage would now continue to climb under its own rocket power to an altitude of 100 miles (160km) and a speed of 6,263mph (10,079km/h).

The payload would have been 2,200 lb (1,000kg) and the anticipated range was in excess of 3,100 miles (5,000km), allowing the A9 to skip down through the atmosphere as it lost speed and reach America's eastern seaboard. The initial targets would be New York and Boston and these plans to attack the US fell within the remit of 'Projekt Amerika', which embraced studies for the design of another spaceplane and several long-range jet bombers. However, the necessity for this missile to have a pilot was high because the construction of a guidance system with sufficient accuracy was some years away. During the flight the pilot would be assisted by radio beacons mounted on U-Boats positioned in the Atlantic and he would make his final course adjustments during the final approach to the target. Another possibility that was considered was to have an undercover operative place a radio beacon near the impact site.

Having set and locked the A9's final course, the pilot would eject. Whether or not this would be the riskiest part of the flight is debatable, but the chances of survival were not especially good. There has been much ongoing speculation about whether the warhead would have contained a normal explosive charge, nerve agent or possibly radiological material, but no definitive documentation has been found to confirm either of the latter.

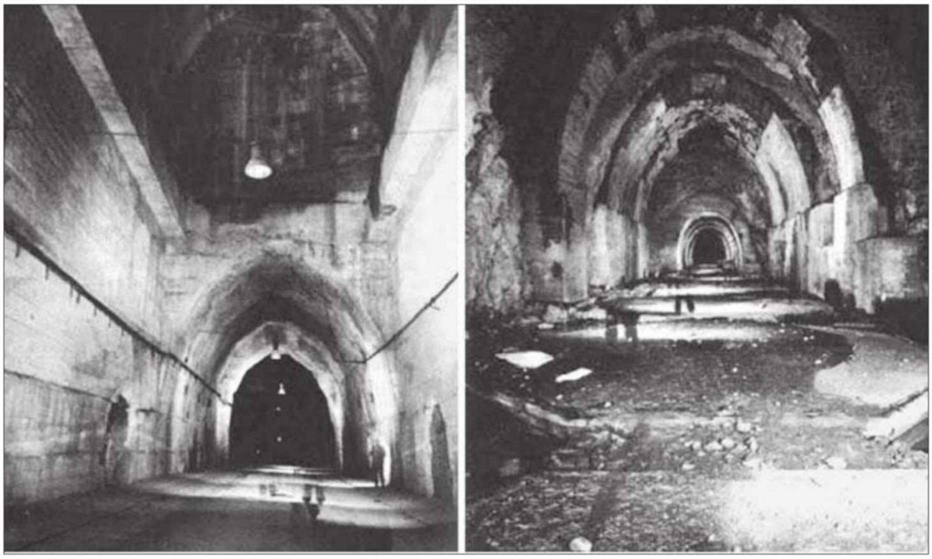
Test Stand VII was built at Peenemünde for use in the A10's development and a progression on to testing long-range missiles was anticipated after the A4 had been approved for production. But following the massive RAF raid on the night of 16-17th August 1943, a high-level decision was taken to relocate much of the rocket facility to other parts of the Reich. One of the places chosen for primarily manufacture of the new A9/10 ICBM was a huge underground complex at Ebensee in Austria. This would be run on similar lines to the Mittelwerk complex and would operate as an extension of the Mauthausen Concentration Camp, using skilled slave labourers for production. The site had originally been intended for use as a totally secure headquarters for the Luftwaffe but this never materialised. The complex was then passed to the SS who decided it was better suited to rocket production.

Using the codenames Dachs (Badger) and Zement (Cement), approval was granted on 20th October 1943 by SS General Hans Kammler to begin work on constructing this massive underground assembly facility beneath the mountains near Lake Traun in Austria. There would be two colossal multistory galleries, Anlage A and B, that were designed for twenty-four hour use by a constant workforce of at least three thousand. Test stands for engines would be built close to the complex and trial launches of the rockets would take place along three separate flight paths, with target areas in the Carpathian Mountains and the Alps. But the site never saw the development and manufacture of A9/10 rockets because there was an urgent need to use the location for refining petroleum and fabricating parts for armoured vehicles. Zement remained in operation until the end of the war, when US Army forces librated this truly satanic facility where thousands had died of malnutrition and exhaustion serving the Reich.



The ambitious A9/10 missile was expected to reach the Eastern Seaboard of the United States from Europe. US Army

A development of the A9/10 considered by von Braun's team would have added a third stage to the rocket and this was designated A11. Utilising a very broad lower stage with thirty-four separate liquid fuel engines, this would have extended the missile's range to most of the United States, and might have made it possible to place a small payload into Low Earth Orbit. After the war Helmut Gröttrup produced numerous rocket designs for the Russians, culminating in a cone shaped missile called the G-4 which was a significant improvement over the A4 and could have delivered an atomic warhead to most of Western Europe. Gröttrup then proposed linking a 'bundle' of his G-4 rockets together into a cone shape around an upper stage. Initially, this concept was known as the R-14 and it became the building block for Korolev's multi-engined R-7 ICBM (NATO designation SS-6 *Sapwood*), which had entered development when Gröttrup and his colleagues



Left: **Pictures taken inside the huge uncompleted Zement facility near Lake Traunsee in Austria immediately after the war. They show (left) the interior of Tunnel 2 and (right) the uncompleted Tunnel 3. (The faint images of figures within these tunnels are US personnel generated by the lengthy time exposures required to secure the pictures).** US Army

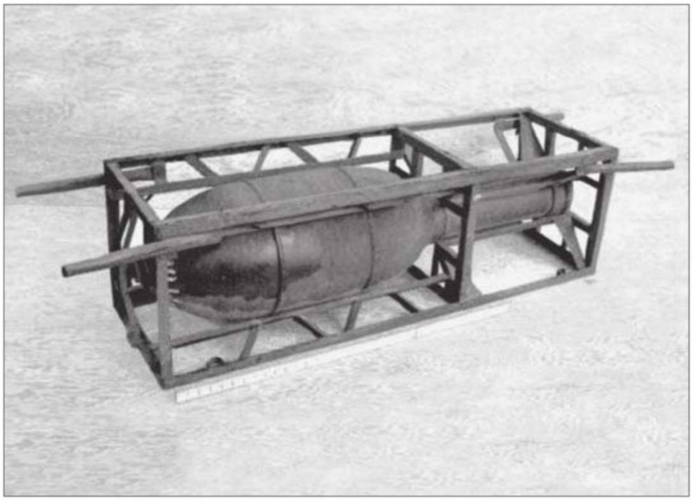
returned to Germany on 22nd November 1953.

The two-stage liquid fuel R-7 was 111ft (34m) long, it weighed 308 tons (279 tonnes) and utilised thirty-two rocket engines. Capable of delivering a nuclear warhead to about 5,000 miles (8,050km) away, the missile was considered too slow to fuel, vulnerable to attack during this period and, once fuelled, the tank seals began to degrade. As a consequence less than ten are believed to have been briefly deployed as nuclear weapons. Modified versions of the R-7 were responsible for putting Sputnik I into orbit on 4th October 1957 and launching Yuri Gagarin into space on 12th April 1961. A crude drawing of the R-14 shows a design that resembles a halfway stage between the wartime German A11 and the Russian R-7, with the influence of the original Peenemünde designers still evident.

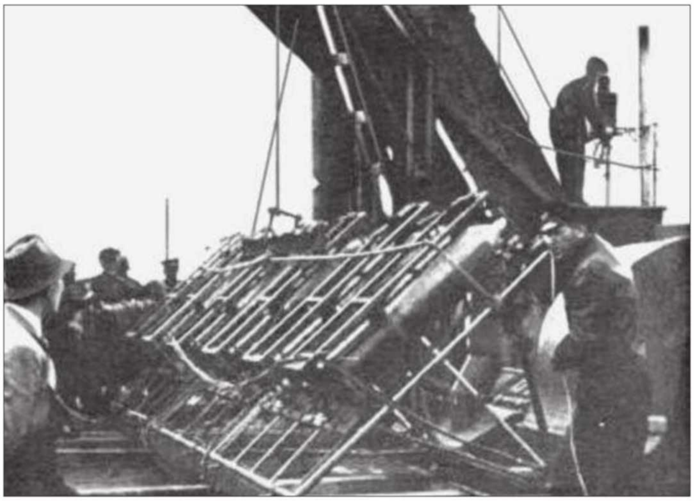
The A12 is considered to be the ultimate Peenemünde rocket design, capable of placing a significant payload into orbit such as a small spaceplane, or delivering a substantial warhead to any point on the globe. After the war von Braun continued to develop this design as a satellite launcher, leading to a massive vehicle capable of lifting manned craft to an orbital space station. Some of his most ambitious designs were for huge reusable booster stages often using as many as fifty rocket engines, but eventually von Braun moved towards fewer, bigger engines and largely abandoned the idea of recoverable lower stages. Returning to the A4/V-2, another use was proposed for this missile which was seriously considered and would inspire a range of future weapon systems.

In 1941 scientists at Peenemünde conceived the idea of launching artillery rockets from the deck of a submarine. The Kriegsmarine showed immediate interest and this led to a series of experiments in 1942 involving U-511, a Type 1XC boat. A Schweres Wurfgerat 41 rocket launcher carrying six 12in (30cm) Wurfkorper Spreng 42 rockets was fitted to the upper deck. Surface launches proved successful, but surprisingly the tests also worked well underwater to a depth of 50ft (15m). The potential for a new anti-shipping weapon seemed good, but there were guidance issues and insufficient resources to push ahead with development. Nevertheless, some progress had been made by the end of the war under a Research and Development programme called Project Ursel.

In 1943 Otto Lafferenz, a director of the Deutsche Arbeitsfront (German Labour Front), suggested the idea of launching V-1 flying bombs from submarines. This was also seriously considered but finally met with rejection for technical reasons. Then in late 1943, during a visit to Peenemünde, Lafferenz put the idea to Dornberger of launching A4 rockets at sea. The missiles were too big to be carried within a submarine and he came up with the idea of developing a submersible container carrying an A4 that could be towed behind a submarine. At a distance of 186 miles (300km) from the target (the A4's normal range) the container would be moved to an upright position and the rocket launched. The idea met with considerable interest and



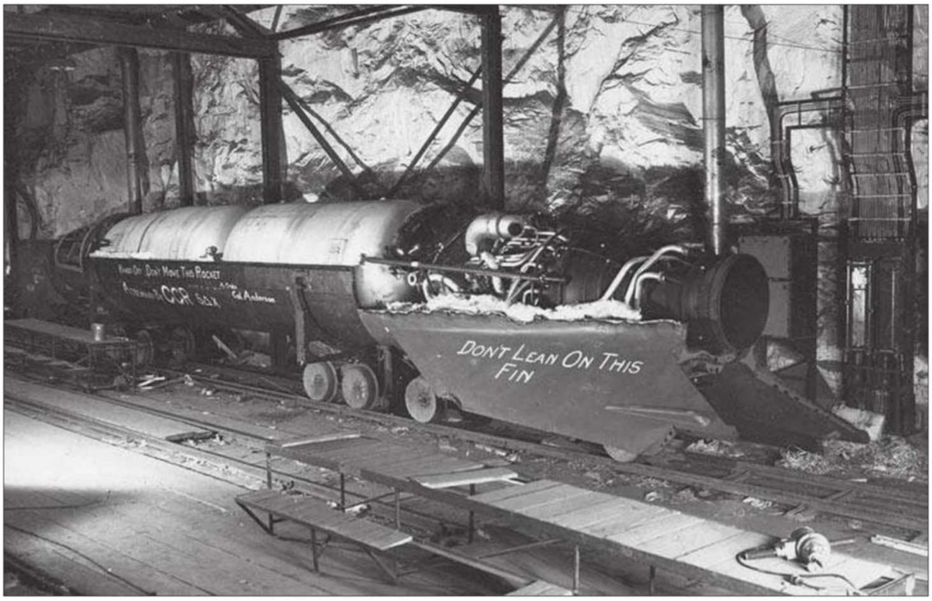
Bottom left: **A small Wurfkorper Spreng 42 rocket used by the Kriegsmarine to test the idea of underwater rocket launching during 1942.** Bill Rose



Bottom right: **Preparations for underwater rocket launching trials with U-511, a Type 1XC submarine.** Bill Rose

Right: **One of the V-2 production lines within the vast Nordhausen facility after liberation by US forces.** US Army

Below right: **A partly dismantled V-2 rocket within the Nordhausen complex awaits shipment to America.** US Army



the codenames Project Prüfstand XII (Test Stand XII), Apparatus F and Life Vest were assigned. But priority was being given to bringing the A4 into operational service with the Army and the development of a submarine-launched missile remained on hold until the autumn of 1944.

Eventually, a submersible torpedo shaped container was designed that measured 98ft (30m) in length and weighed 550 tons (499 tonnes). Access was gained by a hinged nose cap and the A4 missile was housed in the forward section. Behind this was a small control room and fuel storage tanks for the missile and extra diesel oil for the submarine. The container was fitted with water ballast tanks and power for all systems was supplied by a cable from the submarine. When the launch position had been reached, technicians would enter the container, prepare the rocket and finally return to the submarine. Following ignition, exhaust gas from the A4 would be re-directed through conduits around the missile and emerge at the container opening. Once the launch was completed, the container would be scuttled.

It was felt that undertaking launches against targets in Northern England and America would confuse the enemy about German rocket capabilities and make it possible to strike a number of previously inaccessible targets. Several Type XX1 submarines would be adapted for rocket launch missions and one of these newer U-Boats could tow three containers, all trimmed for neutral buoyancy. Conversion of the submarines would be undertaken by Blohm & Voss in Hamburg and Wesser AG in Bremen. However, development of the project faltered and only one of three experimental containers had been completed in the Schichau Dockyard at Elbing by the end of the war. The biggest concern was ensuring container stability during launch while the accuracy of the missile's flight presented a number of challenges that were never resolved. It is also worth mentioning that twelve dismantled A4 rockets were supplied to the Japanese and these were shipped from Bordeaux during August 1944 on U-195 and U-219, arriving in Djakarta in December 1944. What became of the wartime Japanese missile programme is unknown.

After hostilities had ceased, extensive measures were taken by all of the major powers to secure advanced German technology and scientists. In the case of the A4, large numbers of missiles were shipped west to the United States or taken east to Russia. This technology was initially duplicated and then improved on by many of the original Peenemünde scientists. Dr Wernher von Braun was now working in America and sold officials his far-reaching ideas for orbital spacecraft and long-range missiles. Captured A4 rockets were soon undergoing exhaustive tests at the massive White Sands Missile Range (WSMR – locally called Whiz-Mer) in New Mexico. The US Navy took an immediate interest in sea-launched ballistic missiles, launching a captured A4 from the deck of the aircraft carrier USS *Midway* on the 6th September 1947. In Russia von Braun's former colleague Helmut Gröttrup and a team of colleagues were now assisting the Soviets to build a copy of the A4 called the R-1, and develop a more advanced missile called the R-2 that was similar to the A8. France and Britain also examined captured German A4 rocket technology, but both countries lacked the financial resources to compete with America and Russia.

During the immediate post-war years several interesting proposals were made for

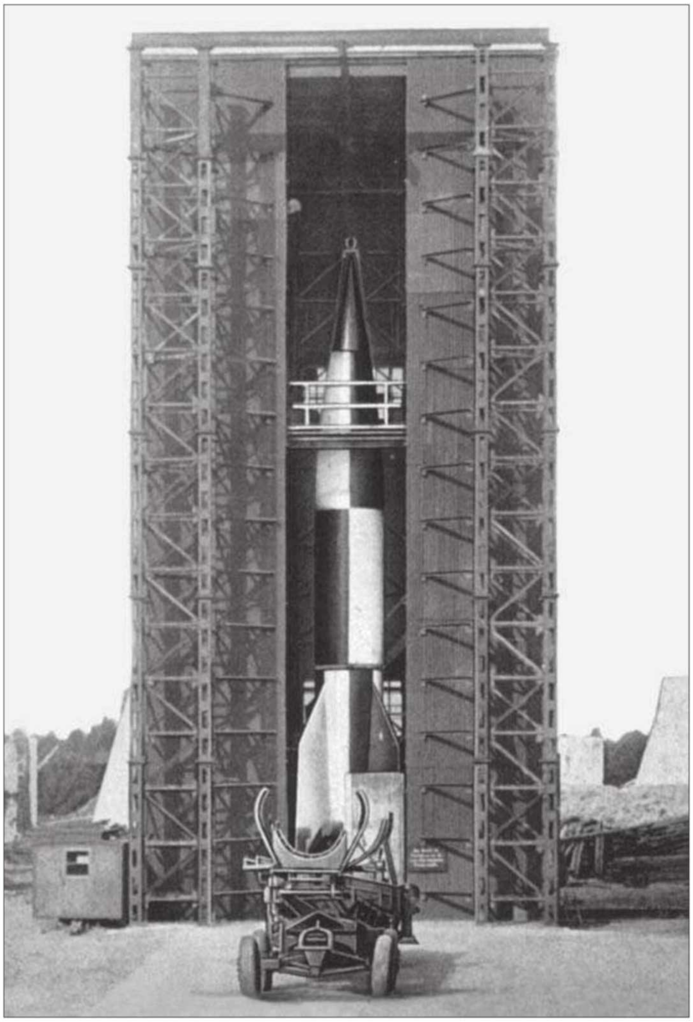
Left: **Operation *Backfire* was a programme organised by the British at the end of World War Two which evaluated all aspects of the V-2 programme, from manufacture and assembly to transportation and deployment. Backfire led to the test launching of three inert V-2 rockets during October 1945 from the former Krupps Proving Grounds in Northern Germany and concluded with the British War Office producing a five volume report on the German V-2 programme. Here a V-2 is taken from storage on a trailer.** Bill Rose

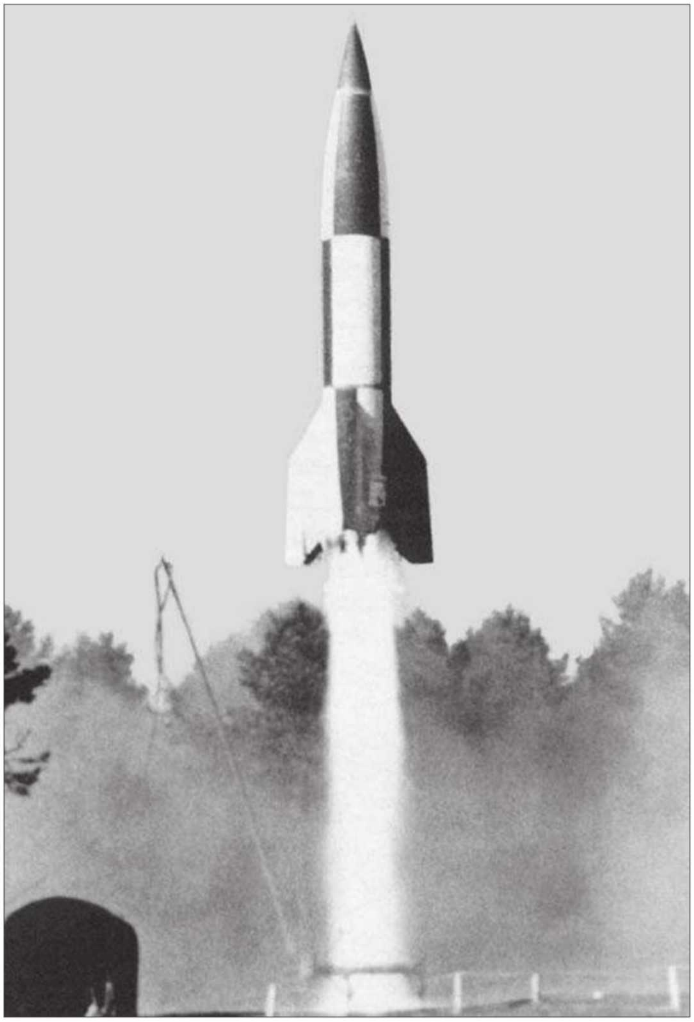
Below left: **A captured V-2 housed in a vertical preparation building.** Bill Rose

Below right: **The first of three V-2 rockets launched during Operation *Backfire*.** Bill Rose

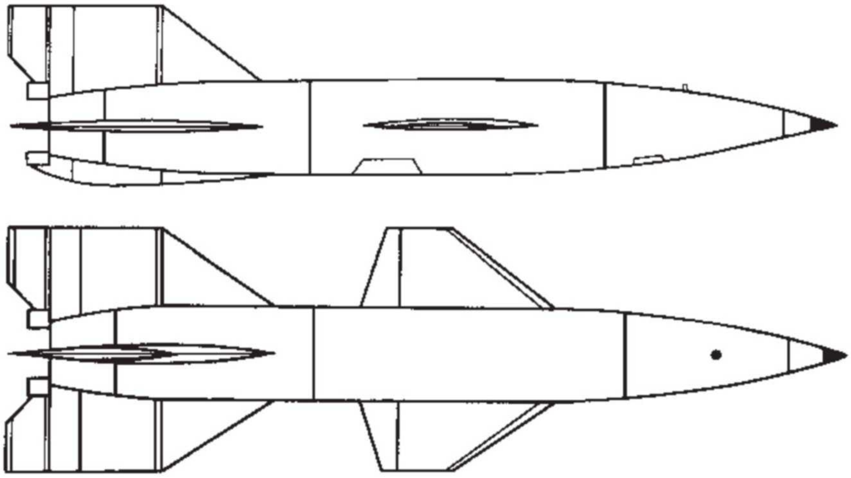
manned rockets based on German designs, starting in 1946 with a study undertaken by a small group within the influential British Interplanetary Society (BIS), headed by R A Smith and H E Ross. They designed a modified A4 rocket which would carry a pressurised detachable capsule capable of carrying an astronaut. Although very risky it was considered technically feasible and might have provided valuable early experience with manned rocketry. Details were forwarded to the British Ministry of Supply who briefly considered the plans and then permanently shelved them. (See the next chapter on British space projects.)

The US Army does not appear to have considered any similar ideas for manned A4 flight, although the newly formed USAF did take some steps in this direction. It obtained several captured A4 rockets for experimental use at Holloman Air Force Base (AFB), which adjoins WSMR, and in 1948 began replacing the warheads with small somewhat improvised pressure capsules capable of carrying animals. Under a programme known as Project Blossom, four A4 launches were undertaken, all of them failed for various reasons and none of the rhesus monkeys inside survived, but Albert 11 launched on 14th June 1949 was taken to an altitude of 82 miles





Right: **A supersonic rocket transport vehicle proposed by the US-based Chinese aerodynamicist Tsien Hsue-shen in 1949.** US Army



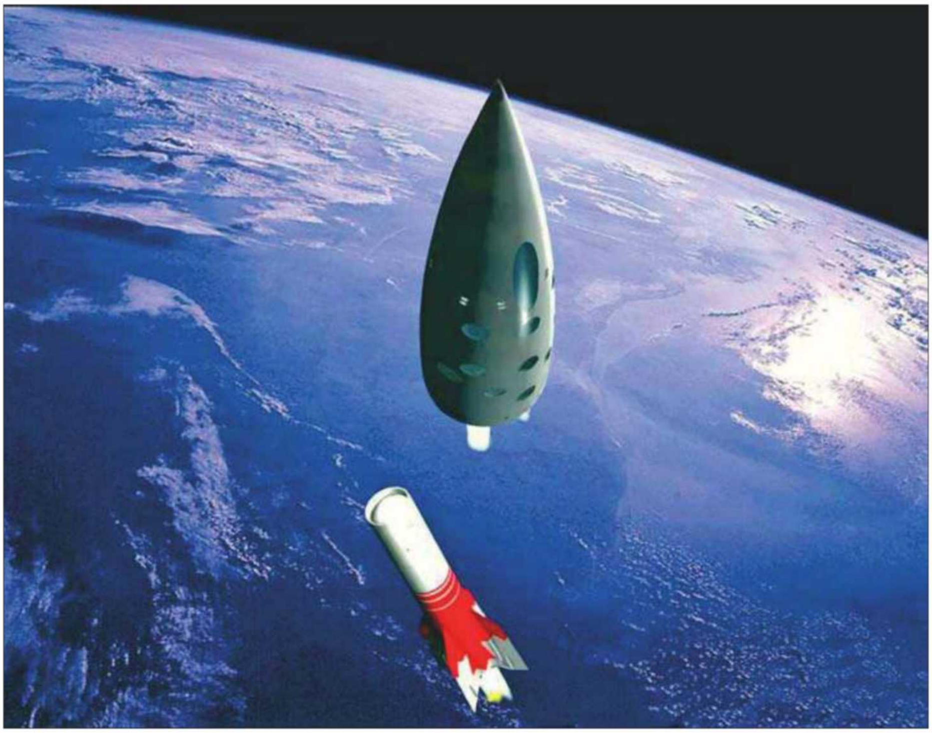
(133km). In 1951 the USAF switched to using Aerobee rockets for animal flights which finally proved successful with the third and final launch in 1952.

During the same period Chinese aerodynamicist Tsien Hsue-shen, who was working in the USA, came up with a serious proposal to develop a rocket based on the A4 as an intercontinental transport. His idea was to build a vertically launched winged rocketplane that could carry ten passengers from Los Angeles to New York in forty-five minutes. This spaceplane would reach an altitude of 100 miles (160km) and a speed of 9,000mph (14,500km/h) under engine power and then coast to a height of 310 miles (500km) before falling back and gliding the remainder of the distance at 140,000ft (42.6km). The design borrowed some features from the German A9, although it utilised small trapezoid shaped wings and was powered by a rocket engine running on liquid fluorine and liquid hydrogen. Hsue-shen suggested the initial construction of a one-man experimental prototype which would have a length of 79ft (24m) and a wingspan of 18ft 9in (5.7m). This was an interesting concept, but no more realistic than the earlier German designs for spaceplanes, and it remained beyond the technical abilities of that era.

A more realistic proposal to achieve a one-man sub-orbital flight, using an R-2 rocket based on the A4/V-2, was made by Russia's chief rocket designer Sergei Korolev in 1955. He put forward plans to use one of these rockets to carry a pressurised capsule to the edge of space and safely return the passenger to Earth. After separation at high altitude, the capsule would come down using a combination of retro rockets and parachutes to slow the descent. It is not known how much further this project was taken but some of the design work almost certainly found its way into Vostok 1, which carried Yuri Gagarin into orbit on 12th April 1961.

Having been deported from the USA in 1955, Tsien Hsue-shen was put in charge of China's fledgling missile programme. Soon afterwards it was decided to utilise Soviet rocket designs and in 1957 two copies of the R-2 missile (known in China as the 1059), along with plans for a compact nuclear fission warhead, were obtained from the Russians. Re-designated Dong-Feng 1 (DF-1), the missile entered limited production. It seems unlikely that the DF-1 was equipped with a nuclear warhead, although it remained in service as a tactical weapon until the early 1960s and was not replaced until 1970, when the more capable nuclear tipped DF-2 entered service.

The A4/V-2 story should have ended at this point, but the rocket made it into the 21st Century with an attempt to place the first private citizen in space. The Canadian Arrow project was set up by entrepreneur Geoff Sheerin of London, Ontario, who hoped to achieve this by using a reproduction A4 rocket with a sophisticated detachable upper capsule. The Canadian Arrow had an overall length of 54ft (16.5m) and could be described as a fully recoverable two-stage vehicle powered by a single 57,000 lb (253kN) thrust liquid-fuelled rocket engine. The three-man crew compartment was fitted with four solid fuel rocket motors which could be used for an emergency launch pad abort. It was planned to launch the Arrow to a height of 70 miles (112km), with the crew compartment separating from the booster section after apogee and both components making a parachute landing into water. The flight was calculated to last approximately fifteen minutes, but the honour of becoming the first private citizen



Right: **The Canadian Arrow manned capsule separates from the booster stage. The capsule's rockets would burn for five seconds carrying it on a ballistic arc to an altitude of 70miles (113km). After re-entry, the capsule would make a parachute descent and splashdown landing.** Canadian Arrow

A full-sized mock-up of the Canadian Arrow rocket displayed at various public meetings during 2003. Canadian Arrow

in space went to Mike Melvill of Scaled Composites, who flew the company's Model 316 SpaceShipOne to a height of 62 miles (100.1km) on 21st June 2004.

An Orbital Spaceplane

Eugen Sänger (1905-1964) was born in Pressnitz, Bohemia, which now lies within the Czech Republic (and in fact vanished beneath the Prisecnice Reservoir when it was completed in 1976). As a teenager Sänger became an avid reader of science fiction and astronomy books, but there were few applications for these interests and when he completed his education Sänger had intended becoming a civil engineer. However, soon after enrolling at the Technical University of Graz in 1923 he read Hermann Oberth's groundbreaking book *Die Rakete zu den Planetenreumen* (The Rocket into Interplanetary Space), and so switched courses to aeronautics. He was soon in contact with the influential Dr Franz von Hoefft (1882-1954) who founded the 'Wissenschaftliche Gesellschaft für Höhenforschung' ('The Scientific Society for High Altitude Research') in Vienna during 1926.

Hoefft was a chemist, engineer and examiner for the Austrian Patent Office. He was also an expert in the early development of rocket fuels and wrote a series of articles for the VfR's journal *Die Rakete* entitled *The Conquest of Space*. Sänger also became involved with the VfR in Germany. In 1928 Hoefft discussed the possibility of building rocket-powered aircraft and Sänger began to develop these ideas much further. In 1930 Sänger joined the Technical University in Vienna, initially as an assistant, and this gave him the opportunity to built and test the first of several liquid-fuelled rocket engines. Over the next five years he designed, tested and eventually perfected a liquid-fuelled rocket engine that was cooled by circulating fuel around the combustion chamber. His 'regeneratively cooled' engine produced a very impressive exhaust velocity of 10,000ft/sec (3,048m/sec). This was significantly better than von Braun's later A4 engine and Sänger was encouraged to apply for a patent for the design, which was finally granted in 1936.

Sänger was convinced that the way into space was by using a rocketplane rather than a rocket and in 1933 he wrote a book called *Raketenflugtechnik* (Rocket Flight Technique), which was published in Austria and served as his doctoral thesis. He described a winged vehicle propelled by a rocket engine running on liquid oxygen and kerosene which was capable of reaching a speed of Mach 10 and climbing to an altitude of 100 miles (160km).

Dr Eugen Sänger, who pioneered the reusable spaceplane concept. Bill Rose

After the book had been privately published Sänger continued to refine the concept, producing proposals for a winged rocketplane that would reach a speed of Mach 13 above the atmosphere, before descending to 150,000ft (46,000m) and cruising at Mach 3 over an intercontinental range. By mid-1935 Sänger had written a series of articles on rocketplanes for the Austrian aviation magazine *Flug*, which set out most of his ideas for a rocket propelled, liquid-fuelled vehicle called Silbervogel (Silverbird).

Seen from a contemporary viewpoint it is easy to criticise the design, but this was an era when the propeller driven monoplane was regarded as state-of-the-art and Sänger's supersonic rocketplane was nothing short of a science fiction concept that belonged to the distant future. While many readers of *Flug* dismissed the Silbervogel concept, it caught the attention of senior officials within the German High Command. They invited Dr Sänger to open a research institute in Trauen for the specific purpose of developing a manned spaceplane. By 1936 Sänger had become a consultant for several aeronautical organisations, although he continued to develop his spaceplane concept for the German military.

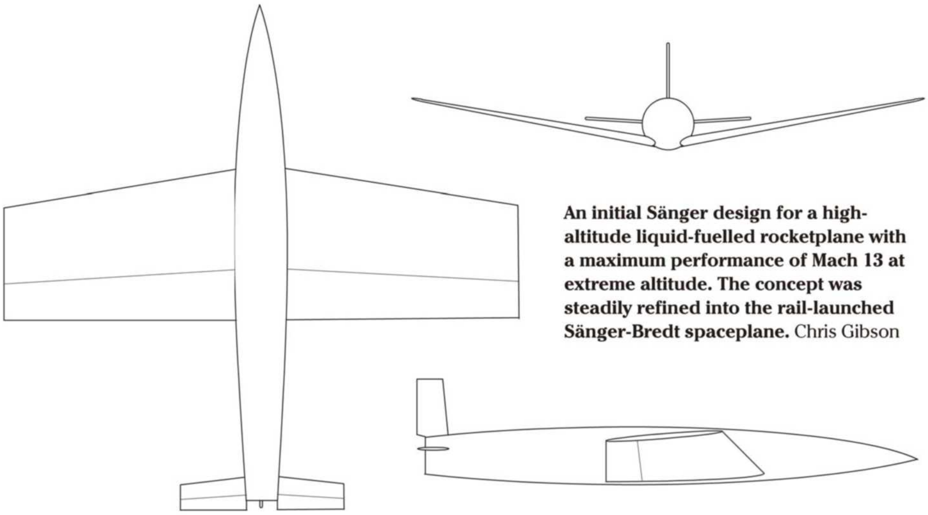
During 1937 Sänger was put in charge of a rocket testing facility at Trauen in Germany and, once the war in Europe was under way, he was encouraged to spend more time working on his design for a military rocketplane. Initially, the Silbervogel concept had been regarded as a ten-year development programme, but there appears to have been increasing pressure to shorten this period after America entered the war. There was now serious interest in finding ways to attack the US mainland and, as a consequence, this project was reviewed and became known as the Sanger Amerika, Stratospheric or Antipodal Bomber.

As design work progressed new workshops and laboratories were built at Trauen and Sänger, assisted by the mathematician Dr Irene Bredt (1911-1983 – one of his students who became his wife in 1951), began to extensively redesigned Silbervogel. They shortened the wings, altered the tail configuration and flattened the fuselage to increase lift. Much of this revision came about as a result of testing stainless steel models in a wind tunnel at relatively high speeds. This resulted in an impressive looking design for a single seat spacecraft with an overall length of 91ft (27.73m) and a wingspan of 49ft (14.93m). These dimensions were principally dictated by the size of the fuel and oxidiser tanks (kerosene/LOX) that supplied the main 100-ton (890kN) thrust rocket engine. Utilising four small supplementary combustion chambers, the engine produced a specific impulse (Isp) of 306 sec (Isp at sea level = 210 sec). The vehicle's empty weight was calculated to be 22,000 lb (9,979kg).

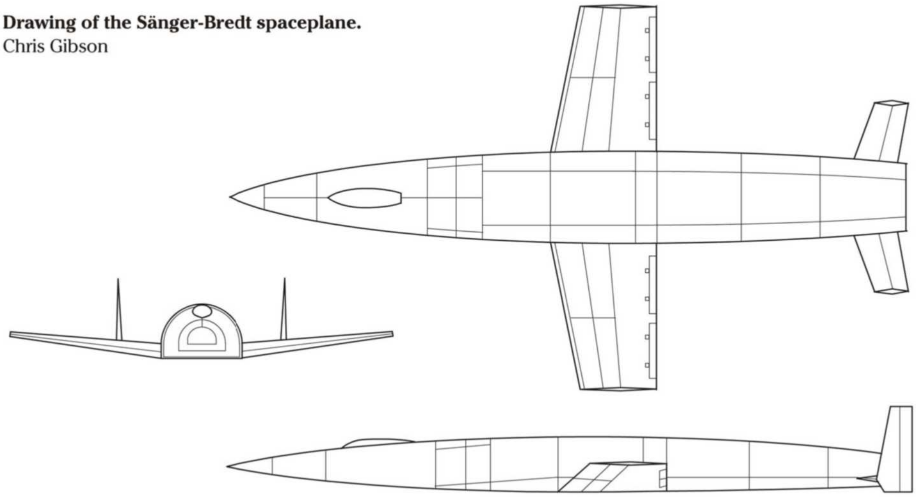
The separate sled booster rocket was little more than an enclosed cluster of liquid fuel engines having a pre-launch weight of 74,000 lb (33,500kg), a length of 46ft (14m) and span of 7ft 6in (2.28m). Fuelled by alcohol and liquid oxygen, the engines would provide a thrust of 600 tons (5,330kN) for ten seconds. The pilot was seated in a pressurised cockpit at the front of Sänger's spaceplane with the windows initially protected by metal shutters. A prone position for the pilot was considered necessary to counteract the launch acceleration, but it was finally decided that an upright seating arrangement would be used because an ejector seat was considered essential.

Although this spaceplane was closer to a missile than an aircraft, it needed to be manned because navigation over long distances was beyond the scope of existing automated systems. The vehicle was supported on a tricycle undercarriage, which allowed an un-powered glide landing like the modern US Shuttle Orbiter, and, despite the low-aspect ratio wings, it was later found that the Silbervogel would have handled quite well at slow speeds. The bomb bay was centrally located in the underside of the vehicle and had a maximum payload capacity of approximately 8,000 lb (3,629kg). The idea was to launch the Amerika Bomber from a 2 mile (3km) long monorail using a rocket stage giving 600 tons (5,330kN) of thrust. This massive booster would burn for eleven seconds and the Amerika Bomber would leave the monorail an angle of 30°. The monorail was considered relatively easy to build, although some aspects of a launch reaching supersonic speed would take the engineers into unknown territory, and there was considerable debate about the use of lubricants with proposals to use a heavy graphite-pitch mixture for the first 10ft (3m) of the rail. Sled braking was a further issue that had not been considered in any detail.

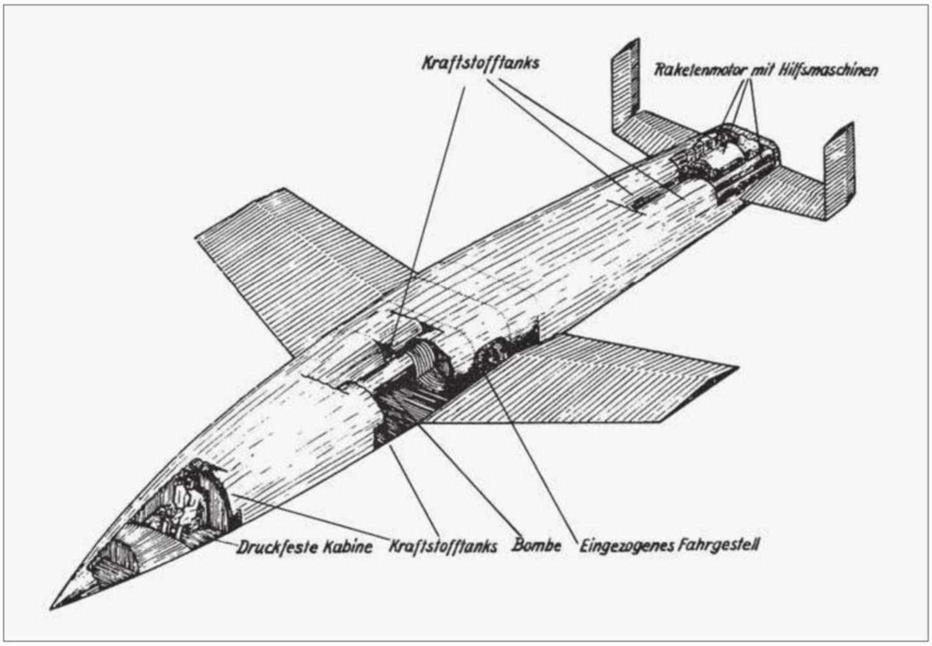
After reaching a height of about 1 mile (1.6km) and a speed approaching Mach 1.5,



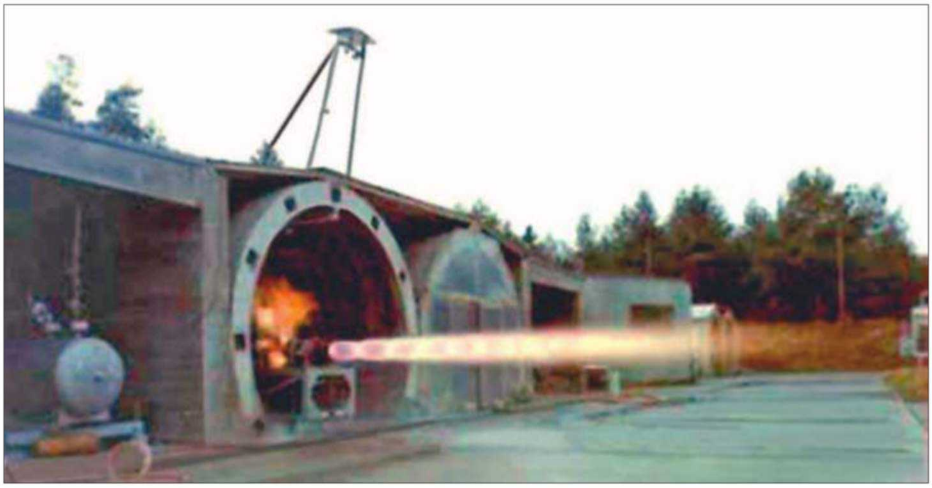
An initial Sänger design for a high-altitude liquid-fuelled rocketplane with a maximum performance of Mach 13 at extreme altitude. The concept was steadily refined into the rail-launched Sänger-Bredt spaceplane. Chris Gibson



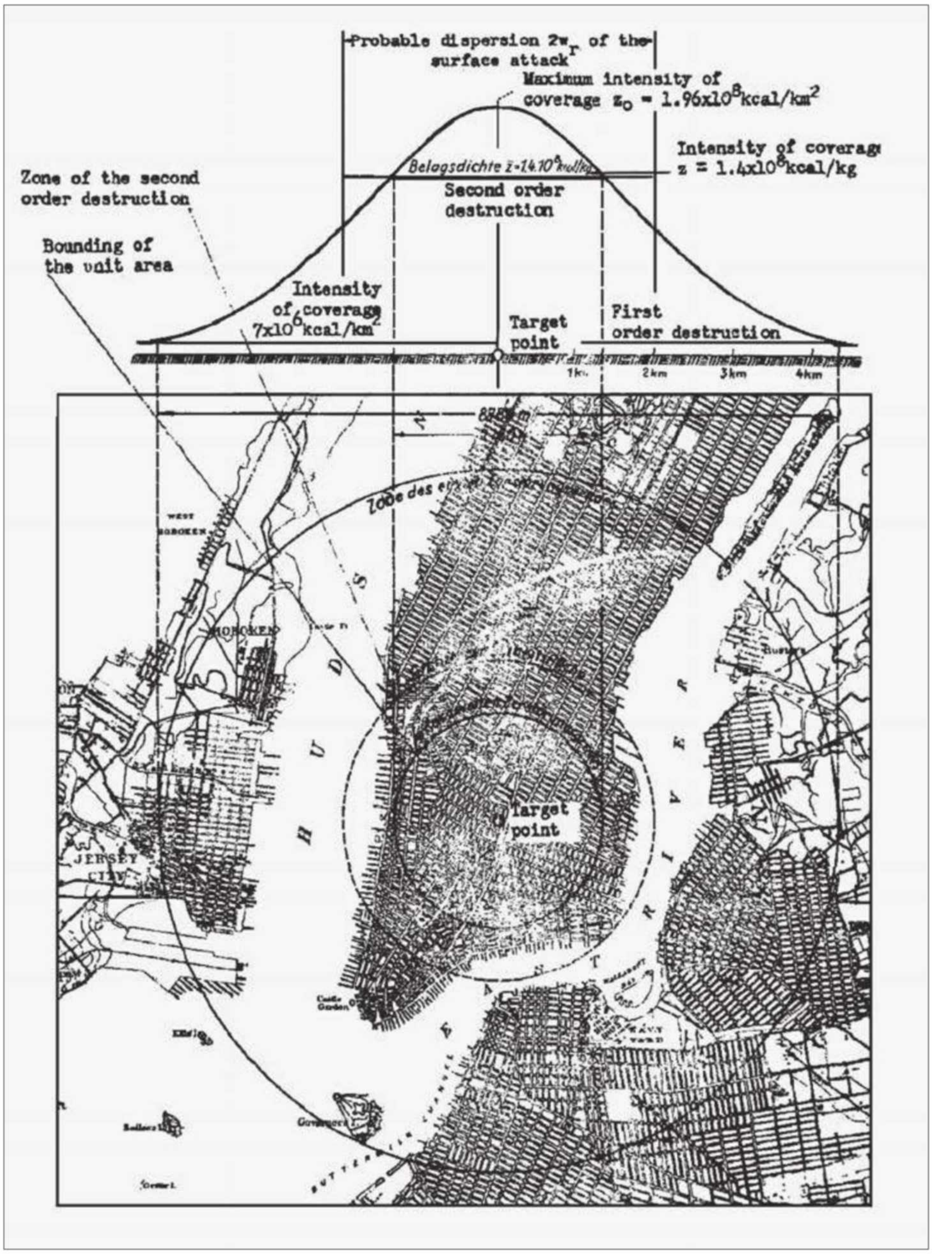
Drawing of the Sänger-Bredt spaceplane. Chris Gibson



Original cutaway drawing of the Sänger-Bredt spaceplane. US Navy



A scale sized liquid fuel engine proposed for the Silbervogel spaceplane is tested at the Trauen rocket facility in Germany during 1942. Bill Rose

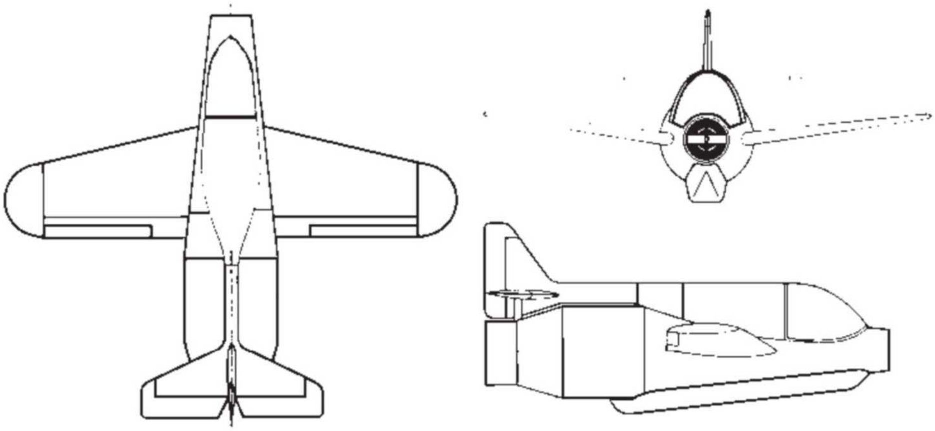

Probable dispersion 2w_r of the surface attack
Maximum intensity of coverage z₀ = 1.96x10⁸ kcal/km²
Intensity of coverage z = 1.4x10⁸ kcal/kg
Belagsdichte z̄ = 1.4.10⁸ kcal/kg
Zone of the second order destruction
Bounding of the unit area
Second order destruction
Intensity of coverage 7x10⁶ kcal/km²
Target point
First order destruction
1km
2km
3km
4km
WEST HOBOKEN
HOBOKEN
JERSEY CITY
HUDSON RIVER
EAST RIVER
Target point
NAVY YARD

Copies of this drawing have been reproduced in various books and magazines, claiming that it shows the effects of a supposed Nazi atom bomb dropped on Manhattan, New York. This is not the case and this original drawing from official US Government archives shows the estimated kinetic energy damage produced by a conventional bomb released from the Sänger-Bredt spaceplane at hypersonic velocity. US Navy

the spaceplane's main engine would ignite and accelerate the vehicle to a velocity of nearly 14,000mph (22.530km/h) and an altitude in excess of 100 miles (160km). Some sources list the maximum altitude attainable as 174 miles (280km) and many aspects of the flight would be variable depending on the mission profile chosen. It is hard to envisage what it might be like to endure such high acceleration during launch, but Sänger insisted that the sled boost would be limited to 5G acceleration and only a little higher during the ascent. Having reached the edge of the atmosphere, the pilot would refine the vehicle's course, choosing from a wide range of options. The vehicle's four auxiliary engines may have been intended to provide exoatmospheric flight control, although there is no discussion about this in any of the available technical documentation. Nevertheless, Sänger must have considered the issues and thought about methods of attitude control as he was aware that the wings and control surfaces would become ineffective at extreme altitude.

If a high precision 'point' attack was required, the spaceplane would cruise for a pre-determined period, then progressively bounce down through the atmosphere (which was expected to assist in cooling the airframe). This technique of bouncing down through the atmosphere, called 'skip glide', finally lost favour in the mid-1950s when the aerodynamicist H Julian Allan, who worked for the National Advisory Committee For Aerodynamics (NACA – the forerunner of NASA) at Ames, determined that it would actually generate unacceptable levels of airframe heating. Interest then switched to boost glide for manned vehicles, although these findings were immediately classified as top secret. It was now apparent that this important issue had not been fully appreciated by Sänger and Bredt and would have led to insurmountable problems if their project had gone forward.

Using Silbervogel as a bomber, the payload would have been released at high altitude and the lightened spacecraft would still have



The Skoda-Kauba P.14 was a proposal for a very basic low-cost fighter aircraft built around a ramjet engine designed by Eugen Sänger. The P.14 would take off from a normal runway using rocket boosters that would propel it to a speed where the ramjet could operate. The wheeled launch trolley would drop away after take off and, having completed its mission, the P.14 would land using a retractable skid. Maximum speed was estimated at 621mph (1,000km/h), it had an impressive ceiling of 60,000ft (18,288m) and an endurance of up to forty-five minutes. The pilot would fly the aircraft in a prone position above the forward air intake and armament was a single MK 108 30mm cannon. Although Sänger's ramjet engines were extensively tested from 1942 through to the end of the war, the P.14 never flew. Bill Rose

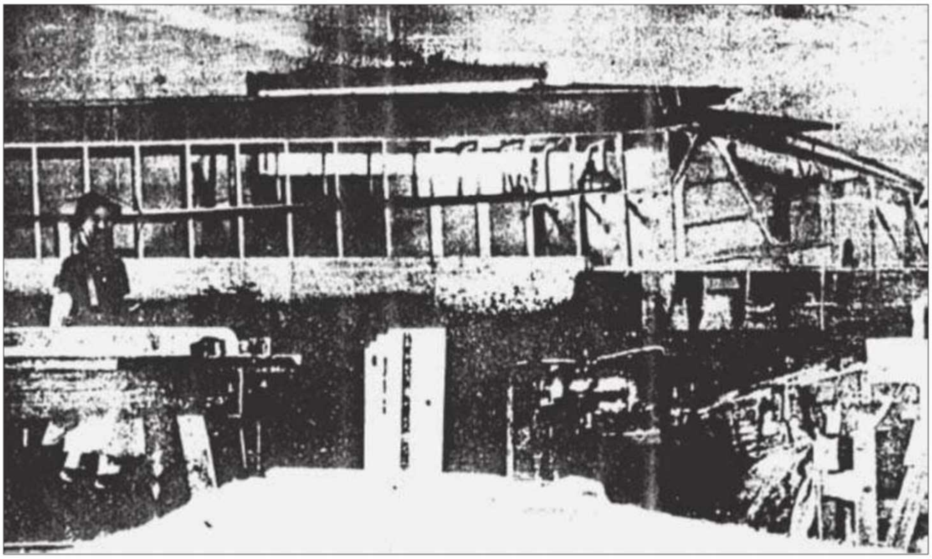
enough fuel to regain some height and attempt to reach a safe landing area. There have been suggestions from time to time that (as with the A9/10 rocket) a dirty radiological or chemical weapon was considered for a strategic attack on a US city, but I have been unable to find any evidence of this and it seems that one or more conventional free fall bombs were all that was proposed. On the other hand, a proposed second type of 'area' attack would have been a different matter and, although somewhat less accurate, the potential for massive damage was considerable. In this scenario the spaceplane would approach the target from an altitude between 165,000ft (50km) and 500,000ft (155km) with the pilot using celestial navigation techniques. At a precise time a single specially designed bomb would be released which would be travelling at a speed of around 14,000mph (22.530km/h). The spaceplane would now change direction and head towards its final destination.

When the bomb impacted at hypersonic velocity its kinetic energy would produce an explosion estimated to be eighteen times greater than a similar device exploded at rest. In a location like Manhattan, New York, the effect would have been devastating, easily surpassing 911 and equalling a small tactical nuclear weapon. It was thought that only a handful of these missions would be required to bring America to the bargaining table. A series of targets were considered for Sänger's spaceplane, with New York and Washington at the top of the list followed by naval ports and the locks at the Panama Canal. Some projected missions would allow the spaceplane to return to base, other possible landing sites were at secure islands in the Pacific Ocean, probably occupied by the Japanese. More risky options required very accurate strikes that could end with the pilot ejecting and the destruction of the spaceplane. Although the spaceplane had a projected maximum range of 14,500 miles (23,300km), or even an orbital capability, it was also considered for short-range attacks against local targets of opportunity within Europe.

Sänger and Bredt continued to develop the spaceplane into early 1942, when scale-size experimental engines were beginning trials and work had started on building the first full-size rocket engine. If the engine development and aerodynamic studies went well a series of flight tests would follow, beginning with trials of models and followed by full sized prototypes that could achieve lift-offs from a long runway under their own rocket power and undertake brief test flights. After that, sled launched tests would begin. However, the war in the East was generating an increasing drain on resources and so exotic, potentially very expensive projects like the Sänger-Bredt spaceplane were pushed into the background. It also became clear that relatively little was known about the behaviour of metals and other materials at ultra high temperatures and work on the spaceplane project at Trauen had virtually come to a halt by 1944.

For the remainder of the Second World War Sänger worked on ramjet aircraft studies for the DFS (with some assistance from his friend Helmut von Zborowski) and he was largely responsible for designing the Skoda-Kauba SK P.14 ramjet fighter which was to be built at Prague. It is somewhat surprising to note that Sänger and von Braun only met twice during the war (in 1940), despite having so many similar interests. When the war ended Sänger and his friend Professor Walter Georgii (1888-1969), who headed the DFS, were detained by US Technical Intelligence and repeatedly interrogated.

These were difficult circumstances but Georgii had excellent contacts within the French government and he introduced them

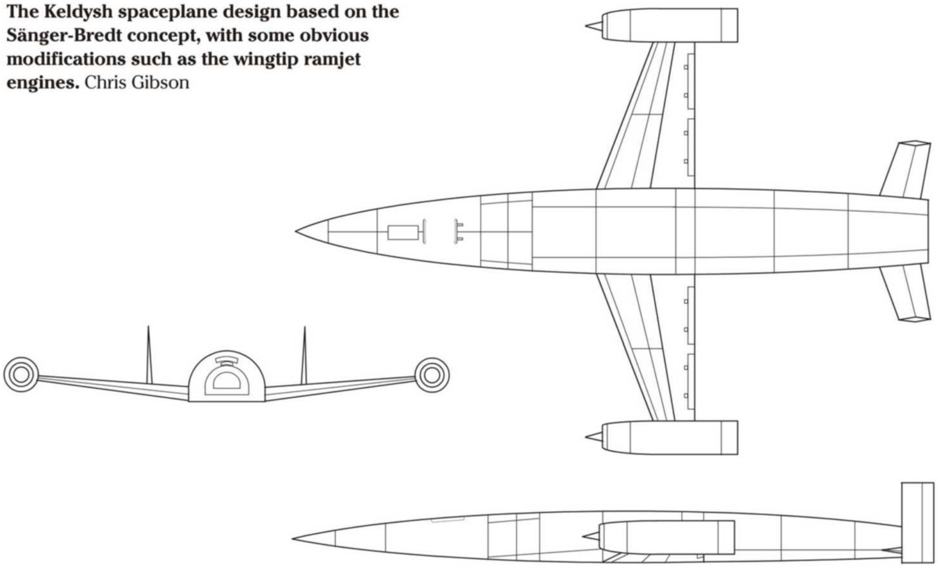


This poor quality image discovered amongst a series of US Intelligence documents dating from 1947 appears to show a mock-up of a Sänger-Bredt spaceplane at a wartime facility near Lofer. US Army to Sänger, which led to an offer of work in France on 30th November 1945. During July 1946 Sänger, Bredt and several associates moved to France and began work for the Arsenal de l'Aeronautique at Châtillon sous Bagneux near Paris (which became Nord Aviation in 1958). As a consultant engineer Sänger worked on a number of different jet, ramjet and rocket propulsion systems and helped to develop the experimental Griffon turboramjet aircraft which first flew in 1957. Other projects Sänger became involved with were the MATRA SS-10 anti-tank missile and R-010 ramjet missile. Meanwhile, much of Sänger and Bredt's research on the Amerika Bomber had fallen into Soviet hands, along with hardware that may have included an uncompleted mock-up of the spaceplane.

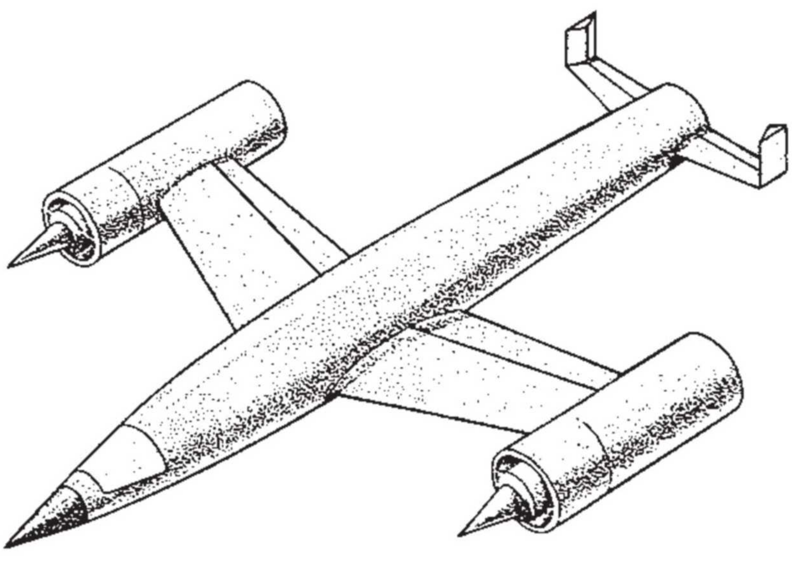
Some US Technical Intelligence documents from 1947 mention the Lofer research facility near Salzburg and there is an indistinct photograph of what looks like the forward section and cockpit of a Sänger-Bredt spaceplane. The caption for this illustration reads 'A futuristic aircraft in a plant near Lofer. It was never flown'. This looks like a mock-up of the rocket bomber and its discovery by the Soviets may have been instrumental in generating significant interest at the highest level. After he was briefed on Sänger's work in early 1946, Soviet dictator Joseph Stalin ordered the NKVD (forerunner of the KGB) to kidnap Sänger and Bredt, who were now living in Paris. Such was the importance of this mission that Stalin's son Vasili, assisted by the enigmatic rocket engineer Grigoriy Tokaty-Tokayev, headed the NKVD team. Stalin also instructed his best scientists to investigate the possibility of building Sänger-Bredt spaceplanes to attack the West with atomic bombs.

On 29th November 1946 Professor Mstislav Vsevolodovich Keldysh (1911-1978) was appointed as the director of an institute called N11-1 KNAP and his brief was to duplicate and improve on Sänger's research. But things did not proceed well and by mid-1947 it was apparent that there were serious problems with the Sänger design resulting from greater than anticipated fuel consumption. Approximately 95 percent of the aircraft's mass would have to be allocated to fuel and the engines required many technical improvements. Keldysh's team progressively modified the Sänger design, leading to a superior vehicle that used wingtip mounted ramjet engines during the initial ascent. The new spaceplane had an original length of 91ft (27.73m), a wingspan of 49ft 2½in (15m), a wing area of 1,356ft^2 (126m^2) and a fuselage cross section of 11ft 9¾in x 5ft 10⅞in (3.6m x 1.8m). Lift-off weight would be 98.4 tons (89.3 tonnes), most of which would be fuel.

The method of launching the vehicle was very similar to the original concept, using a 1.86 mile (3km) long rail and a booster sled fitted with six RKDS-100 rocket engines providing 600 tons (5,330kN) of thrust for eleven seconds. This would accelerate the spaceplane to 1,100mph (1,770km/h) when it reached the end of the track. The spaceplane would then begin to climb under the power of its own 100 ton (890kN) thrust RKDS-100 rocket engine and additional wingtip-mounted ramjet engines, taking it to an altitude of 65,600ft (20km) and a speed of Mach 3. The ramjets would continue to function until the vehicle reached an altitude of approximately 120,000ft (36km), having provided a total Isp of 500 sec. Then the Keldysh spaceplane would continue its ascent under rocket power. Fuelled with liquid oxygen and kerosene, the RKDS-100 would produce an Isp of 285 sec. The maximum speed attained would be in excess of 11,000mph (17,700km/h) while reaching an estimated height of 100 miles (160km) and the range would be approximately 7,500 miles

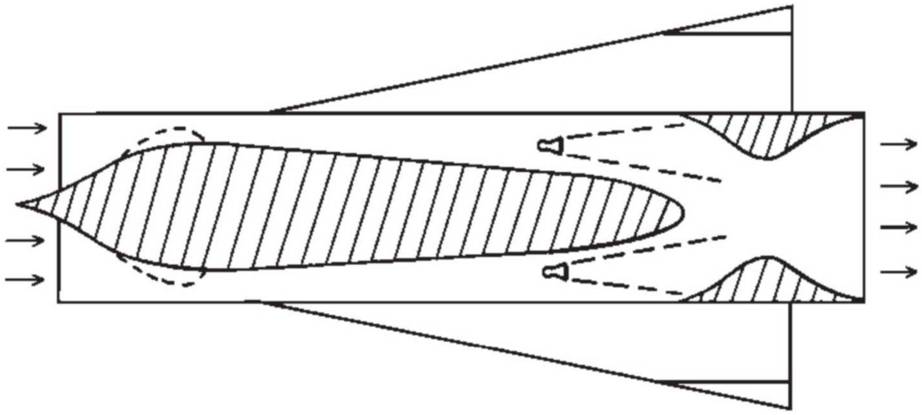


The Keldysh spaceplane design based on the Sänger-Bredt concept, with some obvious modifications such as the wingtip ramjet engines. Chris Gibson



Stalin was so impressed with the Sänger-Bredt spaceplane that he attempted to have the Sängers kidnapped and also ordered Professor Mstislav Keldysh to reproduce their design. Although the Keldysh project is generally considered to be an improvement over the original concept, the design proved unworkable and the Russians eventually abandoned it. Bill Rose

The final design produced by Dr Eugen Sänger in 1964 for a ramjet/rocket powered spacecraft.
Bill Rose



(12,000km). The landing speed was calculated as 124mph (200km/h). Payload capability would be similar to the original design, but this would be a single, relatively low yield fission bomb.

The Keldysh design represented a significant improvement over the original Sänger-Bredt concept, but it was realised that many years of intense development lay ahead to make the system viable. In addition to engineering solutions for untested high-speed sled launching, there would need to be scientific breakthroughs in the field of heat resistant materials and a better understanding of hypersonic flight. Of course, these were exactly the same problems that Sänger had identified some years earlier. The Russians also considered the development of a reliable and accurate automated navigation system as a high-priority and considered this unachievable within the specified time frame.

Meanwhile, the NKVD's undercover operation in Paris to kidnap the Sängers came to nothing after French Intelligence became aware of the situation. The possibility of building a Soviet spaceplane capable of attacking America was slipping away and Keldysh's team realised that the technology was a long way from realisation. Keldysh would reluctantly advise Stalin that the spaceplane was simply too far ahead of its time to be viable. At best it might be ready for testing by the mid-1950s, although this was on the basis of several technological advances being made. As a consequence, development of the Sänger-Bredt spaceplane was abandoned and the focus switched to ICBMs and the less demanding Buran and Burya projects.

While the rail-launched spaceplane remained technically unachievable, Hollywood put Sänger's concept to good use in the 1951 movie *When Worlds Collide*, which won director George Pal an Oscar for best special effects. However, interest in the Sängers was not confined to the Soviets. In April 1952 the former Director of Peenemünde, Walter R Dornberger, and his colleague Krafft Arnold Ehricke (1917-1984), who both worked for the Bell Aircraft Company, travelled to Paris in the hope of recruiting the Sängers. Bell's scientists were actively studying the skip glide technique and favoured the flat style of spaceplane designed by Sänger. But despite Dornberger's best attempts, the newly married Sängers were unwilling to re-locate to the United States. It is also believed the British approached the Sängers with an offer but the couple also turned this down. They chose to remain in France and act as consultant engineers for the French Air Ministry until 1954, when both were offered posts at the Stuttgart Technical University.

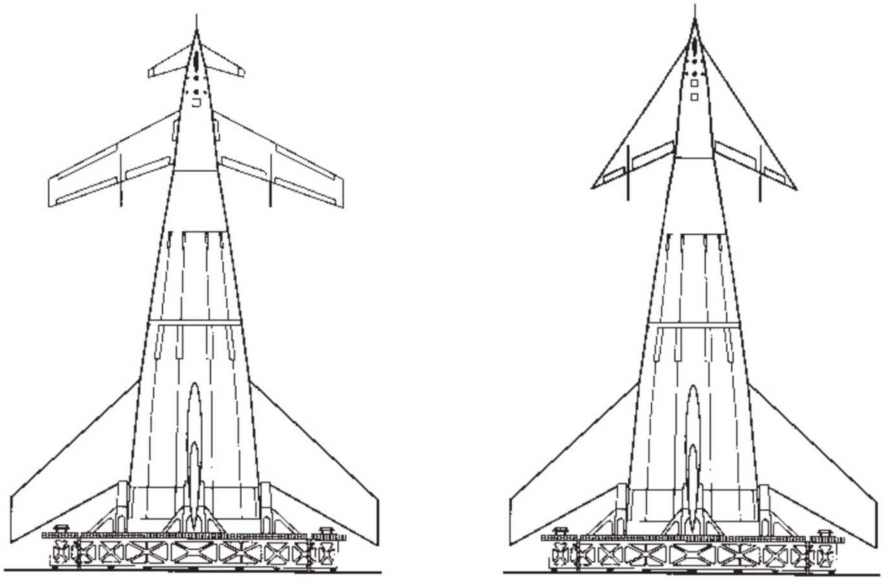
Sänger continued to refine his ideas and in 1961 was retained as a consultant for the reformed West German Junkers Aviation Company, where he completed studies on a more advanced track-launched delta winged spaceplane system capable of delivering 2 to 3 tons (1.8 to 2.7 tonnes) to an LEO. Generally referred to as the Raumtransporter (space transporter), this system was an evolutionary development of Silbervogel comprising of a captive rocket booster and a fully reusable two stage spaceplane system that separated at high altitude. Sänger investigated the idea for a steam-propelled captive booster to achieve maximum economy, but this was finally dropped in favour of a more conventional and simpler liquid fuel rocket system. The Raumtransporter continued to be studied in West Germany during the next three decades, with Messerschmitt-Boelkow-Blohm producing proposals during the 1980s for a runway launched two-vehicle system dubbed the 'Sänger Spaceplane'. While working for Junkers Sänger was accused of assisting Egypt's military with the development of ballistic missiles and, as a consequence of this scandal, he resigned from his University post in November 1961. Irene Sänger-Bredt resigned her position in June 1962.

In October 1963 Eugen Sänger accepted a professorship at the Berlin Technical University. He was now working on a two stage to orbit space system, which comprised of a large Mach 7 mothership operating from a conventional runway that carried a smaller spaceplane in piggyback fashion for launch at extreme altitude. It was a very sophisticated design but, like Silbervogel, remained beyond the engineering capabilities of that time. On 10th February 1964 Sänger died unexpectedly of a heart attack while delivering a lecture at the Berlin Technical University. He was 58 years old. Irene Bredt lived for another nineteen years, receiving the Hermann Oberth Gold Medal for her scientific work in 1970.

What If?

For decades there has been speculation on how much further German wartime rocketry might have progressed if history had taken a different course. Such a question is very difficult to answer, although German rocket technology was far in advance of every other nation and individuals like von Braun produced some remarkable plans which might have been developed by the Nazis given enough time. Had Britain reached a settlement with Germany in 1941 – which appears to have been under serious (although never publicly discussed) consideration by the British Cabinet – it is unlikely that the US would have become involved in a European conflict.

A period of regional stability would have followed and the Germans might have landed astronauts on the Moon by the early 1960s. Alternatively, if D-Day had been delayed or even failed there is every chance that the A9/10 missile would have eventually entered service and been used against the United States. Attacking the US mainland might have led to a ceasefire, or at least bought the Germans some extra time, and by the late 1940s von Braun's scientists might have launched a small Earth satellite, perhaps followed by a risky manned flight to the edge of space. There is no way of telling if the US would have used an atomic bomb against



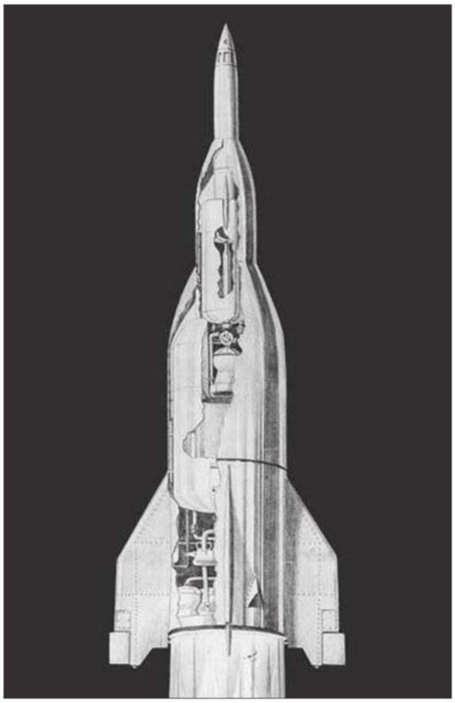
Left: **Drawings for two von Braun manned rockets based on work undertaken during World War Two. As the concept evolved after the war, von Braun made a number of modifications to the spaceplane's upper stage, which included moving to a delta winged design.** US Army

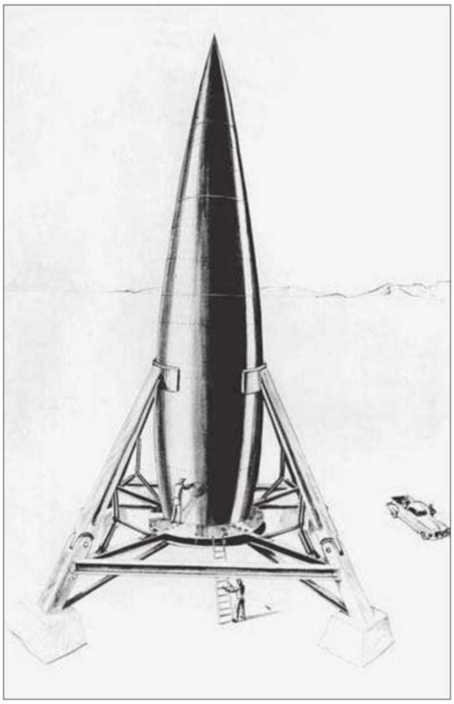
Below left: **A huge multi-stage rocket proposed by von Braun which would have had intercontinental range as an ICBM and been capable of placing a modest payload into orbit.** Bill Rose

Below right: **An over-ambitious von Braun design for a single-stage-to-orbit vehicle. It generated major interest within military circles and helped to secure jobs in America for von Braun and his team after World War Two.** NASA

Germany in a prolonged European war and it is still unclear just how much progress the Germans really made with their own nuclear weapon project. This has been the subject of heated debate for decades and the full details appear to remain hidden from the public. But there can be little doubt that the use of an atomic bomb by either side would have brought fighting to an end and it would have had a major impact on conflicts taking place in other parts of the world.

These issues aside, it is clear that most of the really exotic weapons under development by the Third Reich were simply too far ahead of their time to be practical. In the case of the Sänger-Bredt spaceplane, it is unlikely that this vehicle could have been made to work. The Russians were unable to develop the concept when they attempted to do so in the late 1940s and the Americans abandoned work on skip-glide flight in the mid-1950s, determining that it was not a practical proposition. In wartime Germany many future space concepts were being actively discussed and manned space operations were considered feasible by the 1950s. Needless to say, orbital spaceplanes and manned space stations would have stayed beyond the economic means of the slave-dependent Third Reich that remained at war with most of the world. It is also true that specialised metals, fuel and other essential resources were always in demand and became scarcer as the Second World War progressed.





In 1928 Hermann Noordung (1892-1929) produced a book called *Das Problem der Befahrung des Weltraums* (The Problem of Space Flight). It was an expansion of Hermann Oberth's earlier work and proposed the assembly in orbit of a wheel-shaped space station that would rotate to provide artificial gravity. He suggested the use of the space station for observation and perhaps for military purposes. Noordung also pioneered the idea of parking a space station in geosynchronous orbit.

This idea was developed further during the 1940s by Dr von Braun, who drew up plans for a wheel-shaped platform which would be assembled from twenty cylindrical sections ferried into orbit by expendable cargo rockets. Each section would be 26ft (8m) long with a diameter of 9ft 10in (3m), and the fully assembled wheel would have a diameter of 164ft (50m) with a central 26ft (8m) diameter power module held in place with cables that used a dish to collect solar energy which was then used to provide electrical power. After the war von Braun refined the design further, increasing its size to a diameter of 246ft (75m) which would rotate to produce 1G for the eighty crew members. This was a very advanced concept with two working levels and a central hub where visiting spacecraft docked.

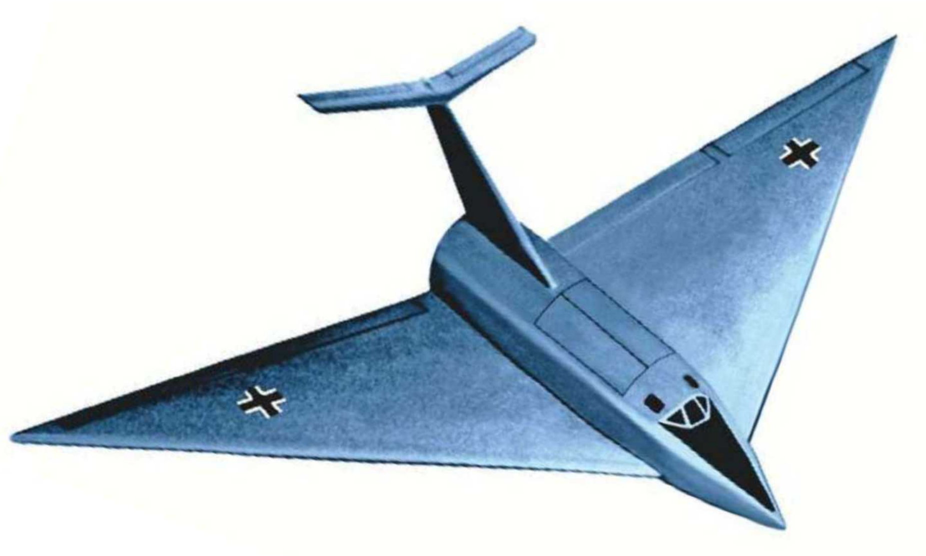
Estimates produced in 1952 for the cost of such a platform indicated that it would take $4 billion to build, which was a staggering amount at that time. Von Braun suggested placing the space station 1,074 miles (1,730km) above the Earth, but this was later found to be unworkable because it would have orbited within the Van Allen radiation

Right: **A hypothetical spaceplane based on a 1950s von Braun design. If the outcome of World War Two had been different this kind of rocket-launched vehicle might have been considered by the Germans for space station re-supply missions.** Bill Rose

Bottom left: **Based on proposals by Herman Oberth for a space observatory, Hermann Noordung developed this wheel-shaped space station in 1929.** NASA

Bottom centre: **During World War Two von Braun developed many ideas for manned spaceflight and one of them was a wheel-shaped orbital space station, which would slowly rotate to produce artificial gravity.** US Army

Bottom right: **Proposed orbital inclination for the early von Braun space station.** US Army

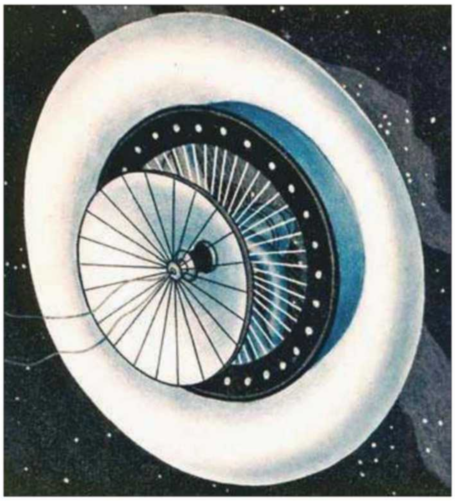


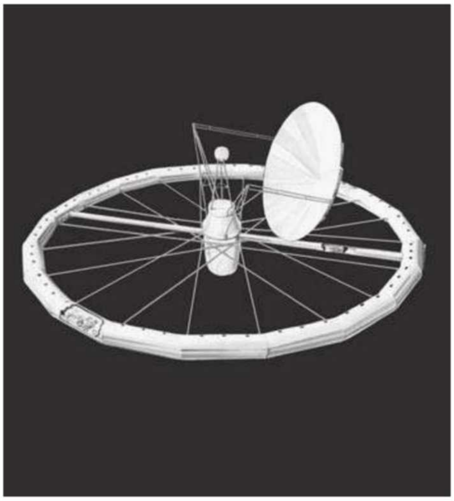
belts. Clearly, the von Braun wheel-shaped space station was several decades away from possible realisation and, although the wheel-shaped design is still considered optimal, it remains un-built.

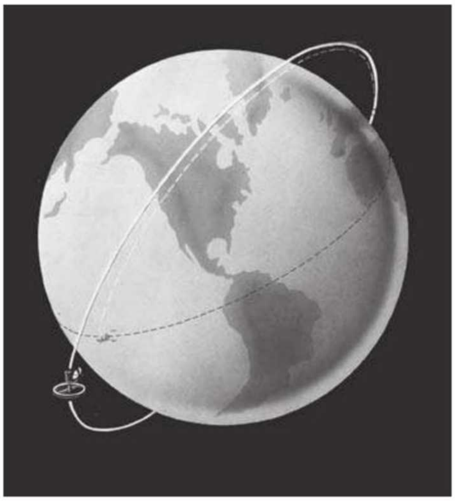
Another space platform concept originating in the early 1920s was dusted off by the Nazis and seems to have generated some interest as an exotic weapon system. During the early 1920s Hermann Oberth had suggested the construction of a colossal orbital mirror with a diameter of 62 miles (100km). His original idea was to bring warmth to particularly cold regions of the Earth and illuminate long winter nights. Oberth continued to develop the idea, considering the effects of a mirror with a diameter of 620 miles (1,000km) which would reflect enough light to keep the Northern Siberian ports free from ice. Oberth believed that the best lightweight material to use for the construction of a mirror was sodium, which remains inert in a vacuum. He suggested that individual sections would be made from paper-thin material attached to a wire mesh backing that would be unfolded in orbit. Once assembled at an altitude of about 500 miles (800km), the position of each individual panel could be remotely adjusted to allow the reflected energy to be spread over a wide area or concentrated in one small location. The electrical energy required to control this huge platform would be provided by solar power.

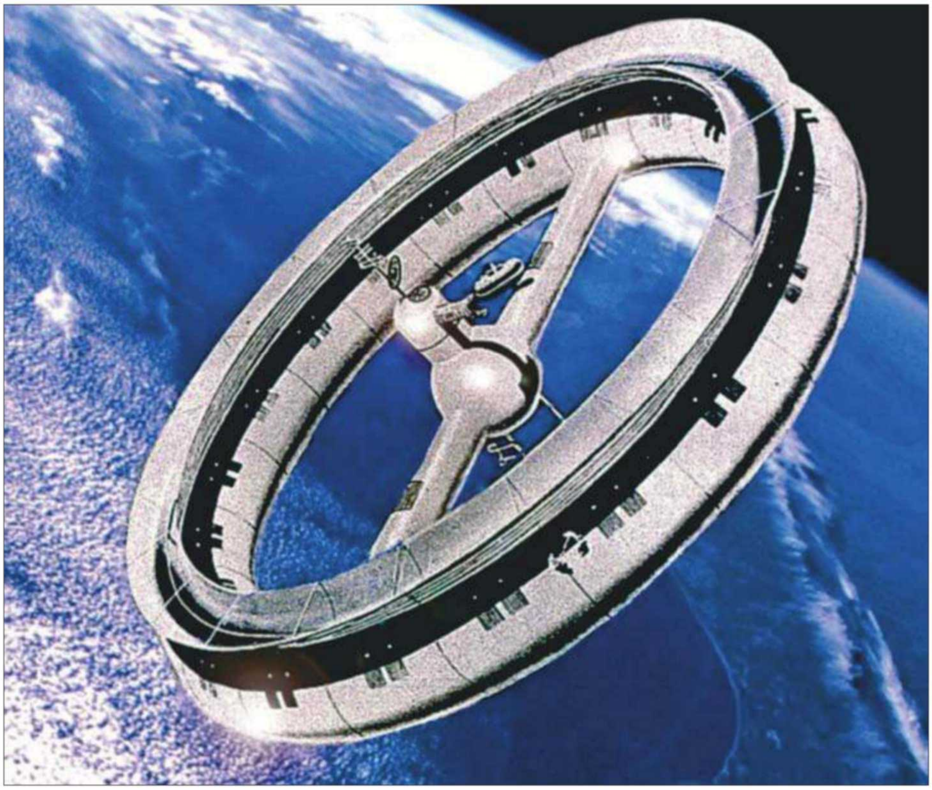
The mirror would have a permanently manned section and Oberth suggested the use of a very powerful telescope to direct, observe and assist accurate adjustment of the area illuminated on the Earth. During the Second World War Oberth worked for von Braun at Peenemünde on the A4/V-2 programme and then moved to the WASAG complex near Wittenberg where he undertook research on solid fuel anti-aircraft missiles. It is not known if he personally attempted to promote the space mirror during this period, or whether the idea was even taken seriously. Hitler lacked enthusiasm for rocketry and would have unquestionably dismissed Oberth's mirror as total nonsense. Calculations suggested that this plan would have cost more than the entire German rocket programme or America's atomic bomb project and taken many decades to complete. It was an unrealistic and unworkable idea but, soon after the war in Europe had ended, the *New York Times* and *Life Magazine* reported that plans had been found for a secret Nazi space weapon, which were based on Oberth's original orbital mirror concept. This death ray in the sky was described as being capable of incinerating cities, blowing up armament plants and vaporising soldiers on the battlefield. Furthermore, nobody would be able to stop it. Quite rightly, the story was met with ridicule by many US and British scientists who regarded it as nonsense.

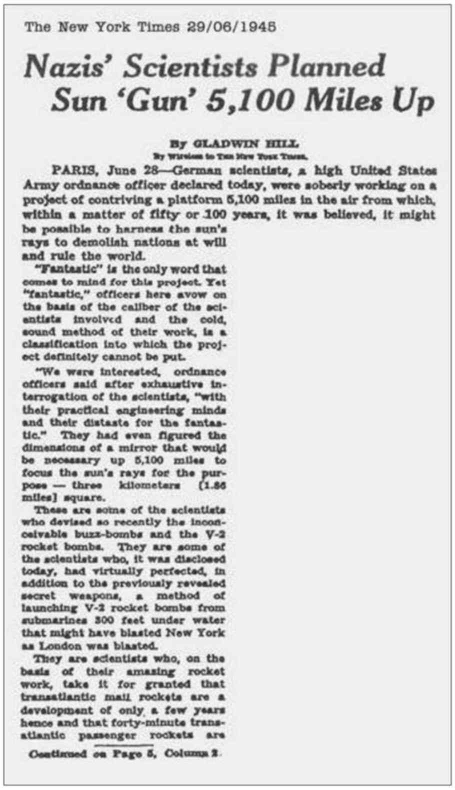
Death rays aside, the basic idea was briefly reconsidered by the US Department of Defense in the 1960s as a way of assisting US ground forces in Vietnam during night-time operations. The Russians also conducted











The New York Times 29/06/1945

Nazis' Scientists Planned Sun 'Gun' 5,100 Miles Up

By GLADWIN HILL

By Wireless to THE NEW YORK TIMES.

PARIS, June 28—German scientists, a high United States Army ordnance officer declared today, were soberly working on a project of contriving a platform 5,100 miles in the air from which, within a matter of fifty or 100 years, it was believed, it might be possible to harness the sun's rays to demolish nations at will and rule the world.

"Fantastic" is the only word that comes to mind for this project. Yet "fantastic," officers here avow on the basis of the caliber of the scientists involved and the cold, sound method of their work, is a classification into which the project definitely cannot be put.

"We were interested, ordnance officers said after exhaustive interrogation of the scientists, "with their practical engineering minds and their distaste for the fantastic." They had even figured the dimensions of a mirror that would be necessary up 5,100 miles to focus the sun's rays for the purpose — three kilometers (1.86 miles) square.

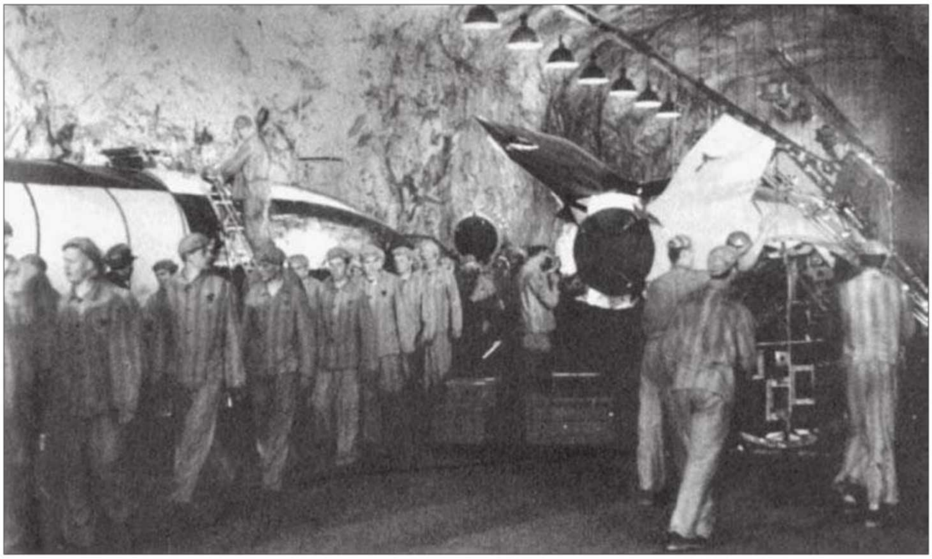
These are some of the scientists who devised so recently the inconceivable buzz-bombs and the V-2 rocket bombs. They are some of the scientists who, it was disclosed today, had virtually perfected, in addition to the previously revealed secret weapons, a method of launching V-2 rocket bombs from submarines 300 feet under water that might have blasted New York as London was blasted.

They are scientists who, on the basis of their amazing rocket work, take it for granted that transatlantic mail rockets are a development of only a few years hence and that forty-minute transatlantic passenger rockets are

Continued on Page 5, Column 2.

experiments with mirrors in the 1990s, under a project called Znamya. The first mirror, called Znamya 2, was carried into orbit by Progress-TM-15 on 27th October 1992. After completing its primary mission of docking with the Mir space station, Progress-TM-15 unfolded the 65ft (20m) reflector. It was then used to produce a 3 mile (5km) wide circle of light with roughly the same intensity as a full Moon, which traversed Europe from France to Russia at 5mph (8km/h). Several hours after this demonstration, the mirror was de-orbited over Canada and burned up. A follow-up experiment took place on 5th February 1999 using an 82ft (25m) mirror called Znamya 2.5, but the reflector snagged on one of Mir's antennas and was badly damaged. The trial was subsequently abandoned and the mirror de-orbited. Plans existed for Znamya 3, which would have been an even bigger mirror with a diameter of 200-230ft (60-70m), but the project was cancelled by the Russian Federal Space Agency, probably for economic reasons.

To summarise on this final section of the first chapter, the Germans had the best scientists available to develop rocketry and were willing to experiment and take risks whenever funding permitted. The Third Reich was supported by tens of thousands of slave labourers who made the vast industrial war machine possible and, without this workforce, hostilities would have ended much sooner. Dr von Braun was a genius who turned a blind eye to the appalling atrocities taking place at facilities like the Mittelwerk Complex, arguably knowing the consequences of voicing any concerns. Nevertheless, without the German V-rockets we would still be discussing the idea of landing men on the Moon today, and the advanced electronics we take for granted would remain speculative topics for technical publications.



Top left: **By 1952 von Braun had taken his proposal for a wheel-shaped space station to a very advanced stage. It was to be enlarged to 246ft (75m) in diameter and be capable of accommodating as many as eighty personnel.** NASA

Top right: **A somewhat unrealistic report about the proposed Nazi orbital space mirror, which appeared in several newspapers shortly after the war in Europe had ended.** Bill Rose

Left: **The German rocket programme was only made possible by the thousands of highly skilled Jewish and Russian prisoners forced to build the Reich's most advanced weapons at Mittelwerk near Nordhausen. This photograph comes from official Russian archives, but is clearly German in origin.**

Chapter Two

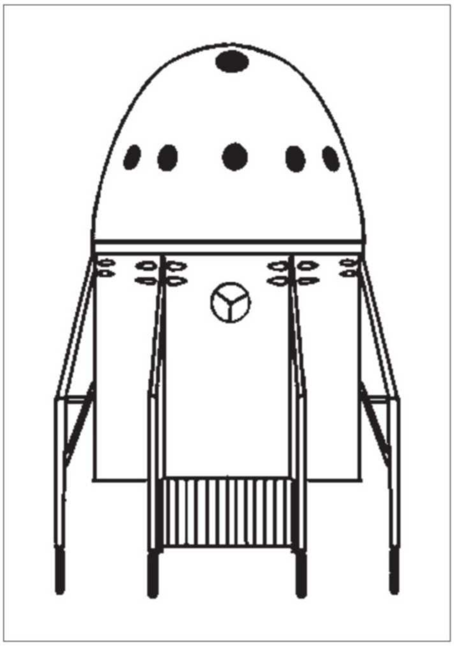
British Space Ambitions

Britain has never come close to building a vehicle capable of putting an astronaut into space and the possibility remains unlikely. But the United Kingdom has always produced good designers and engineers with plenty of ideas for undertaking just such a project. Since World War Two ambitious plans to develop a manned space capability have generated several peaks of interest (mostly within the military), but there has never been the funding or political will to make this possible.

The history of serious British spacecraft design dates back to 1937 when a small very talented group of individuals within the newly formed British Interplanetary Society (BIS) decided to begin a study on undertaking a manned Moon mission. The group was led by J Happien-Edwards and included H Bramhill, Arthur C Clarke, A V Cleaver, M K Hanson, Arthur Hanser, S Klemantski, H E Ross and R A Smith. To most people living in the 1930s the idea of a Moon mission had more in common with a Flash Gordon sci-fi movie than reality. It was something that might be considered in the next century but, realistically, nobody was going to see a man on the Moon in his or her lifetime. But members of the BIS group believed that a Moon mission could be undertaken within the not-too-distant future, providing there was enough public support, a modest amount of scientific progress and a great deal of money.

The basic design of a Moon rocket was the first thing the team decided on and they chose a solid fuel system for propulsion. Solid fuel was regarded as the most advanced technology available at this time and opinions about this remained unchanged until after the Second World War. The Moon rocket would be 100ft (30.5m) high, it had a diameter of 20ft (6.09m) and an approximate weight of 1,102 tons (1,000 tonnes). The 2,490 solid propellant rockets would be contained within the vehicle in conical layers that would fall away after use. Three crew members would be housed within a lunar lander/command module at the top of the rocket and this had a calculated weight of about 2,204 lb (1,000kg). Launched from the equator, the crew's capsule would be protected by a jettisonable ceramic heat shield capable of withstanding 1,500°C during the ascent; however, interestingly, no consideration was given to protecting the capsule during re-entry into the Earth's atmosphere. During flights to and from the Moon it was felt necessary to slowly rotate the vehicle at one revolution per 3.5 seconds to induce artificial gravity. The air supply would be fully re-cycled and navigation would be undertaken with basic instruments.

Liquid fuel rocket engines were proposed to make adjustments during descent to the Moon's surface, with steam jets being used for attitude control. Equipped with hydraulic legs the lander would make a soft touchdown on the lunar surface and the crew would leave the vehicle via an airlock wearing rubber and leather spacesuits designed by H E Ross. Although this hardware seems rather quaint by modern standards, the pressure suit design utilised most of the key features that would appear in US Apollo suits such as an oxygen supply in the backpack, temperature control and a radio. Having completed their stay on the Moon's surface, the crew would lift off and return to the Earth, finally making a parachute descent. Some aspects of the proposal were clearly unworkable but, considering that these plans appeared in print during 1939, it is hardly surprising that nobody was able to suggest any improvements until 1947. This took the form of a fresh BIS study which re-evaluated the original proposal and took into account major German advances in liquid fuel rocket motors.

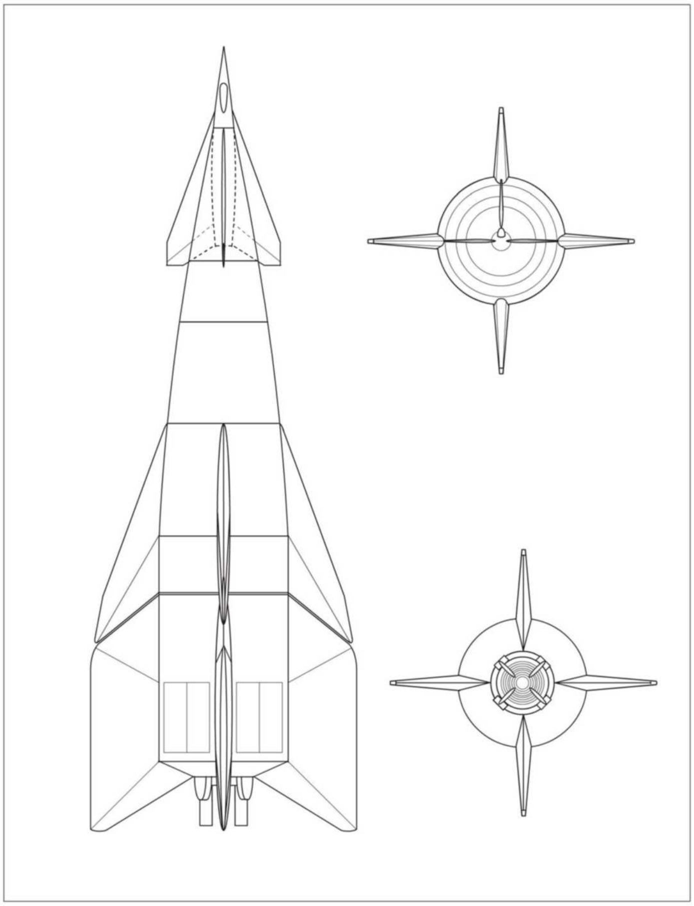


The BIS (British Interplanetary Society) Moon lander, based on an original pre-war drawing. Bill Rose

Megaroc

In the immediate post-war years, there was intense professional interest in utilising German rocket technology for military and research purposes. The Germans had shown the way forward with high-performance rockets using liquid-fuelled engines and some of their most advanced projects, like the A9/10 rocket and the Sänger-Bredt spaceplane, seemed more like science fiction concepts. Harry E Ross and Ralph A Smith were both engineers who had been members of the 1930s Moon Rocket Study Group within the BIS and they now turned their attention to utilising a German military A4 rocket for the purpose of putting a Briton into space. The design of this rocket differed considerably from von Braun's man-carrying winged A9 and they called it Megaroc. This name was derived from the terms of reference for the project, which were to carry a man to an altitude of one million feet (189 miles/304km) by rocket.

To meet their performance requirements Ross and Smith suggested lengthening the propellant tanks, removing the aerodynamic fins and positioning a pressurised one-man capsule where the warhead would normally be carried. The turbopump section would be re-located to impart a degree of gyroscopic stability during ascent and the capsule would separate from the rocket at burn-out. The capsule would be equipped with attitude thrusters and descent would be controlled by parachute. The rocket would also return to the ground by parachute and might be largely re-usable. No consideration seems to have been given to re-entry heating and the capsule would have made a splashdown landing.



The probable location for a Megaroc flight would have been Australia, although this does not seem to have been specified. Ross and Smith submitted their plans for Megaroc to the Ministry of Supply (MoS) on 23rd December 1946 and the proposal was briefly considered, but then shelved. Whether or not this concept would have worked (if a suitable heatshield had been developed during testing) remains debatable, but a manned flight would have been extremely risky.

Ross-Smith Space Glider

Having completed the Megaroc study the talented Ross and Smith team turned their attention to the design of a five-stage launch system which would be capable of placing a small spaceplane in orbit. Smith was working for the Rocket Propulsion Establishment at Westcott and took advantage of this to draw on the considerable technical expertise of his colleagues. The multi-stage rocket, which he developed with Ross in 1951, would have an overall length of 165ft (50.3m) and use a series of liquid-fuelled engines based on the A-4 design. It would have a finspan of 59ft 6in (18.1m) and a maximum core diameter of 28ft (8.53m). Each stage of the rocket would utilise a single high performance liquid fuel rocket engine and the gross weight of the rocket was set at 2,535 tons (2,300 tonnes). It is clear that the launch vehicle owed a great deal to wartime German designs and was based on the A-4 and A-10/11. Rocket engines were equipped with A4-style graphite steering vanes and parachute recovery was proposed for the first three stages to allow refurbishment and re-use. The booster would lift a small delta winged spaceplane or cargo container into orbit. The overall length of the spaceplane was to be 50ft 3in (15.3m) and it would have a span of 27ft 10in (8.47m). The design of this vehicle shares some similarities to concepts produced at the same time by von Braun, but this spacecraft is said to have been inspired by early experimental Avro high-speed research aircraft designs.

Sometimes referred to as a Space Glider, this vehicle would carry three men into orbit and utilise a single liquid fuel rocket engine. However, the term glider refers to the way it would return to base like the US Space Shuttle. This craft had an estimated mass of about 6.6 tons (6 tonnes), while the alternative expendable cargo container was to deliver about 5.5 tons (5 tonnes) to orbit. Launched from an equatorial site, either vehicle would be able to achieve an orbit of 500 miles (800km). This was a very serious design project based on sound engineering methods for a re-usable spacecraft system. It owed much to German rocketry and rivalled any other study conducted during the same period.

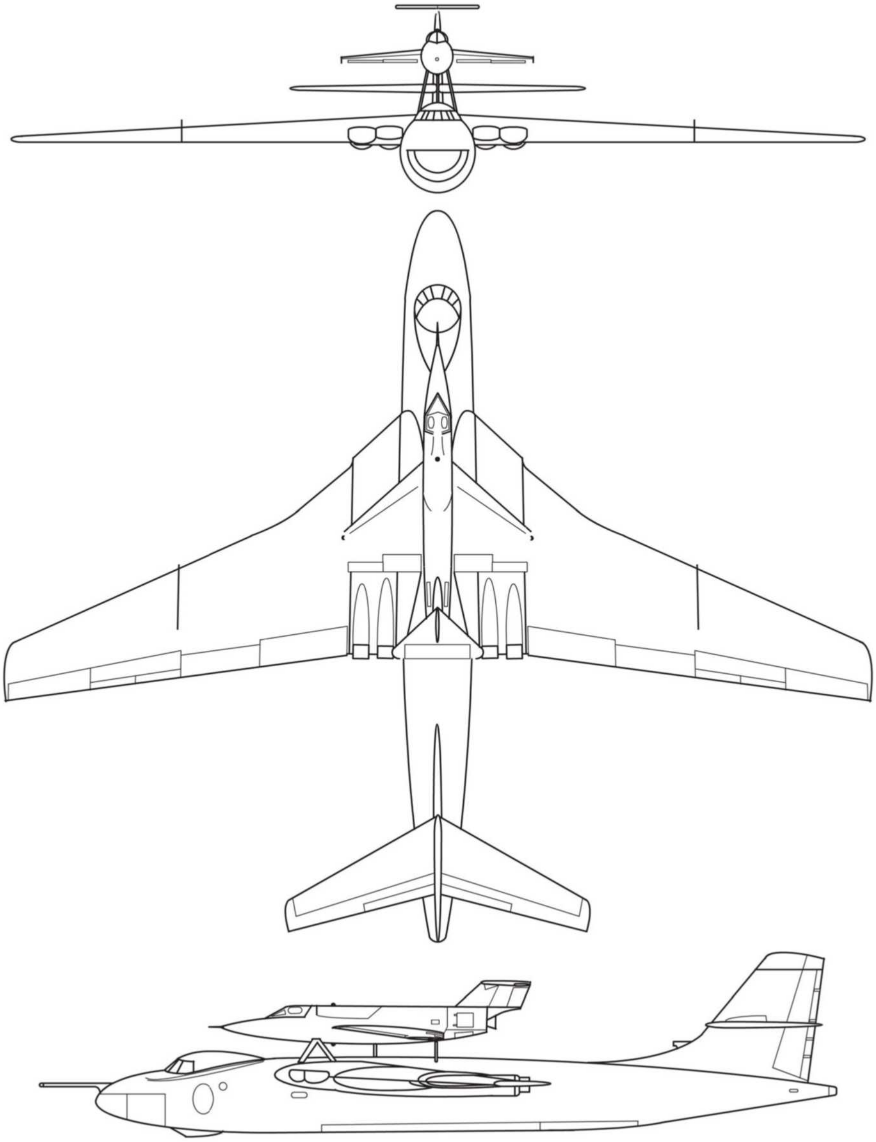
Above left: **Megaroc designed by BIS members immediately after World War Two and intended to carry a British astronaut to an altitude of 189 miles (304km).** Bill Rose

Above right: **A sophisticated multi-stage booster and spaceplane designed by BIS members Ross and Smith.** Chris Gibson

Saunders-Roe High-Altitude Rocketplane

In 1951 the UK Air Staff issued a set of requirements for a high performance interceptor capable of countering the anticipated next generation of Soviet bombers. This came about because there was growing concern, on both sides of the Atlantic, that by the early 1960s the Russians would be operating nuclear bombers capable of cruising at an altitude of 60,000ft (18,200m) and travelling at speed approaching Mach 2. The requirements came together within Specification F.124. Although initially excluded from the competition, Saunders-Roe made representations to the MoS suggesting the company

The single-seat Saunders-Roe SR.53 prototype mixed propulsion interceptor. SARO Archives



A high-altitude development of the SR.53, launched from the back of an adapted Vickers Valiant bomber. Chris Gibson

would like to participate in the development of a rocket interceptor under the direction of their chief designer Maurice Brennan.

The MoS had been impressed with German wartime pure-rocket interceptors and was giving serious consideration to design submissions like the delta wing Short PD.7, which promised a phenomenal rate of climb. However, Brennan finally managed to convince MoS officials that a secondary jet engine (a feature of his design) was essential, insisting it was needed for controlled landings. This proposal met with immediate approval and during 1953 the MoS upgraded F.124 to F.137 (to cover the Avro 720 project) and F.138 (for the Saunders-Roe design), favouring mixed propulsion. Saunders-Roe was then requested to begin development of its project. Assigned the reference SR.53, this aircraft would use an Armstrong Siddeley Viper ASV.8 Mk.101 turbojet providing a thrust of 1,640 lb (7.29kN) and one de Havilland Spectre 3A rocket engine with a thrust rating of 8,000 lb (35.5kN) at sea level. The single-seat SR.53 was 45ft (13.7m) in length, had a wingspan (without missiles) of 25ft 1in (7.65m) and a height of 10ft 10in (3.30m). Gross weight was 18,361 lb (8,329kg) and the aircraft was configured to carry two de Havilland Firestreak missiles on its wingtips.

By late 1953 the original specification had been updated and the requirement now called for an interceptor with the ability to cruise at 75,000ft (22,860m) and have supersonic performance available at all heights above 30,000ft (9,144m). It was hoped this aircraft could be in RAF service by 1957. The MoS then began to consider a production aircraft to supersede the SR.53 and the best submissions were presented by Avro and by Saunders-Roe, who planned to develop the SR.53 into a more capable aircraft called the SR.177. Although the Avro design was considered good, the SR.177 was finally chosen for RAF and Royal Navy service because Saunders-Roe had more experience in this field than Avro. A mock-up of the SR.177 was completed in the Saunders-Roe factory at Cowes and towards the end of 1956 the company was starting to fabricate components for the first batch of aircraft.

The single-seat SR.177 would have a length of 50ft (15.2m), a wingspan of 30ft (9.1m) and a height of 14ft (4.3m). Gross weight was calculated at 25,500 lb (11,570kg). A single de Havilland Gyron Junior DGJ-101 turbojet engine would provide 14,000 lb (62.2kN) of thrust with reheat and would be supplemented by a Spectre 5A rocket engine with a rating of 8,000 lb (35.5kN) thrust at sea level. It was anticipated that this aircraft would have a performance in excess of Mach 2 and a service ceiling of better than 70,000ft (21,300m). The SR.177 was to be equipped with an air interception radar system and two de Havilland Red Top missiles. However, as a consequence of a controversial UK Defence White Paper announced by Minister for Defence Duncan Sandys on 4th April 1957, a number of advanced programmes were cancelled including the SR.177. The cost-cutting White Paper favoured missiles for air defence and suggested that manned fighters would soon be obsolete. As a result the only new interceptor to survive was the English Electric Lightning.

Despite this, the first SR.53 (XD145) undertook its maiden flight at Boscombe Down on 16th May 1957 and was flown by RAF test pilot Squadron Leader John Booth. It had been decided that the SR.53 should continue as a missile test-bed and the second prototype (XD151) was completed and flown before the end of the year. Unfortunately, XD151 was destroyed in a crash at Boscombe Down on 5th June 1958 when it hit a concrete pole on take-off, killing Booth. The cause of the accident was never fully explained and investigators could find nothing wrong with the aircraft. In total, forty-two test flights had been made but XD145 would never fly again and no further prototypes were completed. Saunders-Roe was now thrown into a state of chaos by Britain, and Germany's, cancellation of the SR.177. The Germans had regarded the interceptor as an ideal replacement for its American-built subsonic F-84 and F-86 fighters. Other overseas buyers were also interested in the aircraft, including Japan. Five or possibly six SR.177 airframes were near to completion at the Cowes factory when the cancellation was announced and there was general agreement that the SR.177 would have been a good aircraft. The RAF had planned to operate it alongside the Lightning.

The 1957 White Paper had led to 1,470 Saunders-Roe employees being made redundant, although the company still tried to interest the Royal Aircraft Establishment (RAE) in the idea of a high performance research aircraft based on the original SR.53. This experimental aeroplane would be capable of attaining very high altitudes and the designers at Saunders-Roe suggested launching it from the back of a Vickers Valiant V-bomber at 50,000ft (15,240m). It would then climb under rocket power to 250,000ft (76,000m), in the process attaining a speed of between Mach 3 and Mach 4.

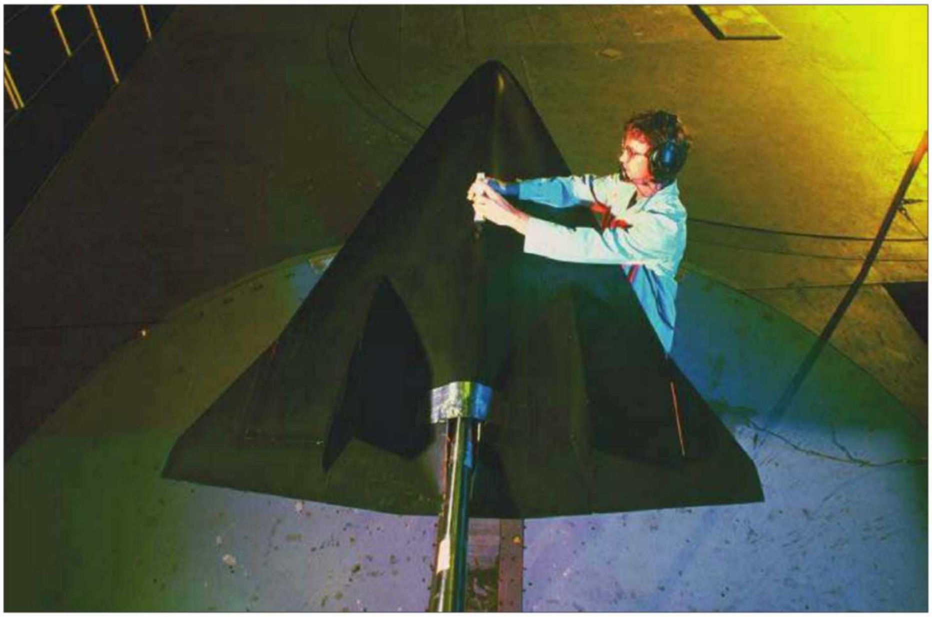
Saunders-Roe went on to suggest that the aircraft could be improved further by completely eliminating the jet engine and replacing it with an even more powerful rocket. In this form they claimed it might be capable of hypersonic performance, competing with the American X-15 (Project 1226) rocketplanes that were already under construction at North American Aviation's plant in Los Angeles. But an SR.53 with this capability would have required a stretched fuselage with space for extra fuel and an airframe and skinning made in a heat resistant metal like stainless steel or, ideally, titanium. The aircraft would also need an attitude control system to undertake ultra high-altitude flight. The idea wasn't completely crazy because in May 1952 extensive modifications to the USAF's air-launched Bell X-2 rocketplane were briefly considered which would have given it the ability to reach the edge of the atmosphere and achieve a speed of about Mach 4.5.

There can be little doubt that the Saunders-Roe rocketplane would have been very costly to develop and it would have been virtually a new design which had little, if anything, in common with the original SR.53. Not surprisingly, the RAE never took up the proposal. This also spelt the end of British interest in rocket-powered fighters as the performance and reliability of gas turbines continued to improve.

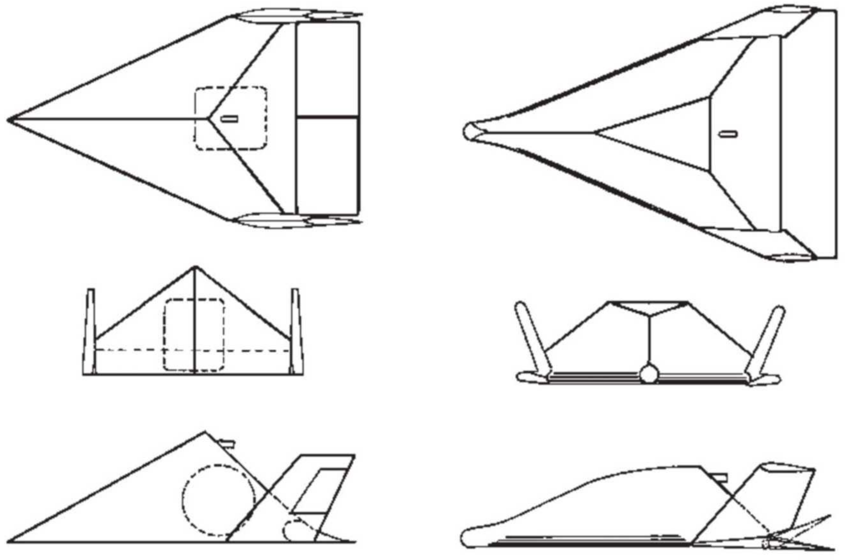
Nonweiler's Waveriders

In 1951 Terence Reginald Forbes Nonweiler (1925-1999), a lecturer in Aerodynamics with the College of Aeronautics at Cranfield, produced an extraordinary design for a spacecraft known as a waverider. He began by configuring a delta-winged spacecraft that would have sufficient surface area to discharge the heat generated during re-entry. However, while refining his calculations Nonweiler realised that the shock wave produced by the vehicle's flight would create high-pressure beneath the wing. This would give lift and the vehicle would be able ride on this wave. When Nonweiler outlined these ideas in a paper on hypersonic re-entry vehicles he had formed the basis of all future waveriding concepts. The vehicles using this principle proved to be somewhat different from the simpler blunt-nosed designs used for missile warheads and manned space capsules, which produce relatively little lift during re-entry and have limited scope for manoeuvre.

Nonweiler subsequently discovered that a sharp nose and sharp leading edges assisted lift considerably and further improved a waverider's ability to glide during re-entry at high altitudes. On the down side this meant that the edges of a waverider would become extremely hot, requiring special heat resistant materials and possibly supported by the use of coolants, and during the 1950s this presented serious engineering problems. They also exhibited aerodynamic difficulties at certain Mach numbers and it was evident that



An 8ft (2.43m) Mach 5.5 model based on the original Nonweiler waveriding concept is prepared for testing in the NASA Langley Full Scale Tunnel during mid-1995. NASA

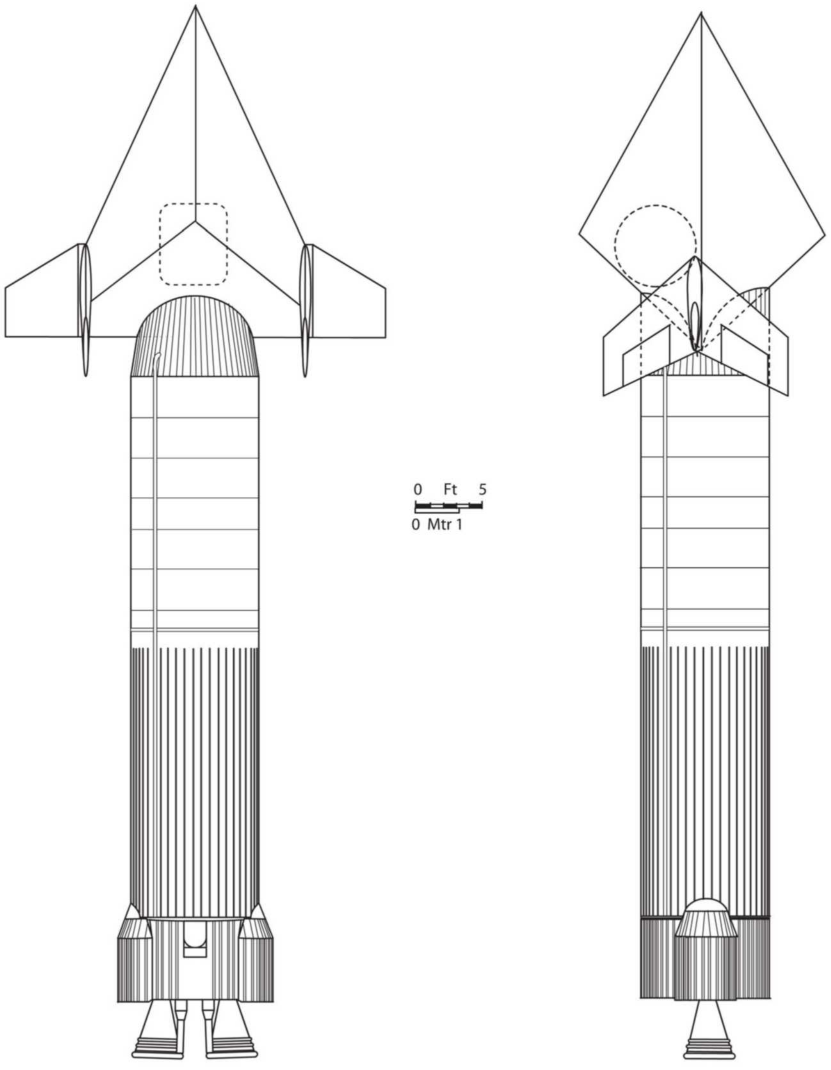


The initial Armstrong Whitworth spaceplane proposal (left) and a more advanced version (right). Bill Rose

satisfactory overall handling, especially at lower speeds, would be hard to achieve. If a chart were to list capsules with fast re-entry and substantial heating at the top and waveriders with controlled high-altitude gliding at the bottom, the US Shuttle would be roughly in the centre of the two. So far the only significant (known) use of waveriding has been a loosely related method known as compression lift, which was proposed by Alfred J Eggers who worked as an aerodynamicist for NACA. This was applied to the design of the experimental Mach 3 North American XB-70 Valkyrie bomber prototype in the late 1950s and came into effect at high speed when the wingtips were folded downwards to create a constricted airflow beneath the aircraft.

The Armstrong Whitworth Pyramid

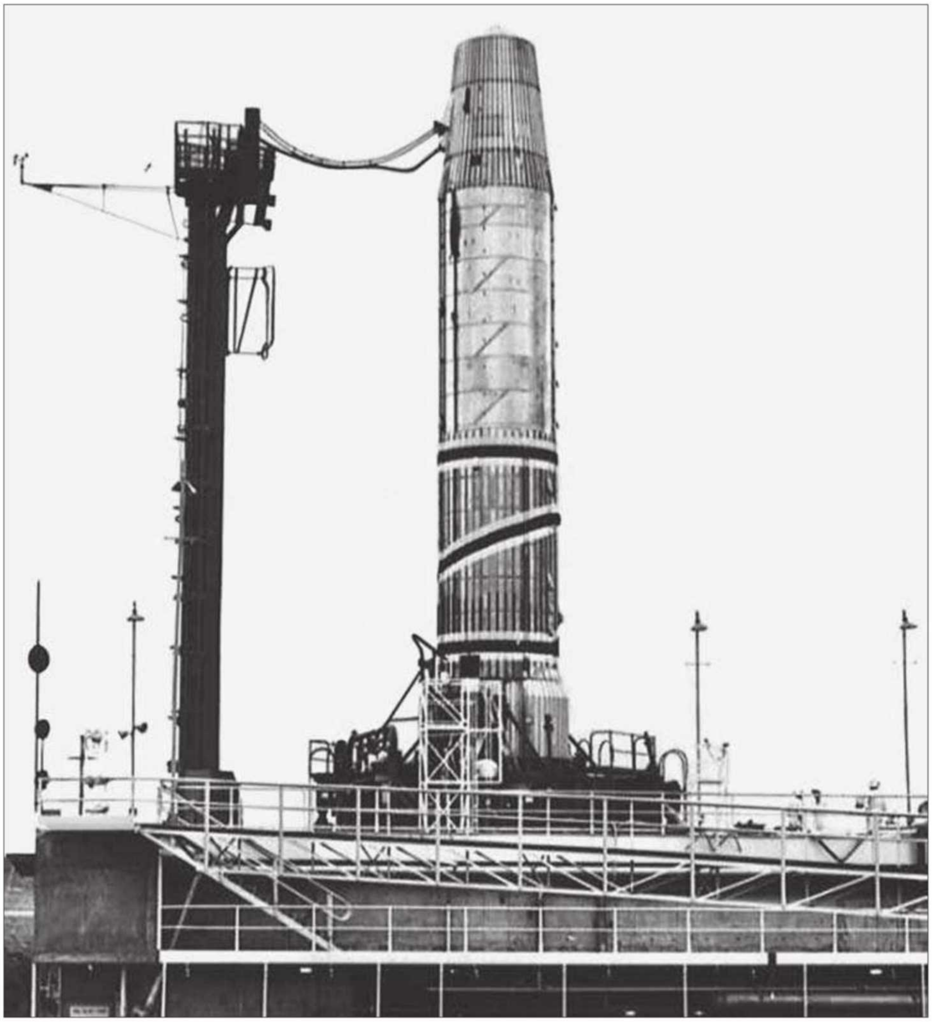
By the late 1950s Nonweiler headed the department of Aeronautical Engineering at The Queen's University of Belfast, but he was retained as a consultant to work on a new British spacecraft project from Armstrong Whitworth Aircraft Ltd. Leading the design team was Henry R Watson, with support coming from Dr Bill Hilton of Hawker Siddeley. The initial ideas for this project are said to have originated in 1954 and the proposal was for a small manned spacecraft which would be launched into space by a Blue Streak rocket (below) on ballistic and orbital flights. To deal with re-entry problems Nonweiler produced an unusual pyramid-shaped design with a completely flat triangular underside, short wings and upright stabilisers. He hoped to reduce re-entry heating by low wing loading, allowing the heat to be conducted up through the fuselage and releasing it into the cooler airflow above the vehicle. The rear wall of the spacecraft would be equipped with an exhaust pipe or vents to ensure there was no significant atmospheric pressure within the fuselage that would reduce heat transfer. To provide aerodynamic symmetry during launch, a lightweight 'image fairing' which carried extra fuel would be attached to the flat side of the Pyramid. This would be discarded after the Pyramid separated from the booster and an attitude control system would be used above the atmosphere.



The Armstrong Whitworth Pyramid waveriding spaceplane with 'image fairing' mounted on a Blue Streak rocket. Chris Gibson

The Pyramid would act as an aerodynamic container for a fully pressurised drum-shaped capsule capable of carrying two crew members, cargo or possibly a military payload. The capsule would be located at the vehicle's centre of gravity and options were considered which would allow the capsule to be ejected rearward from the Pyramid after re-entry to make a parachute descent. It was suggested that the pressurised capsule might be fitted with small aerodynamic surfaces, but it remains unclear if the Pyramid would make a controlled landing or a parachute descent. It is also possible that no escape methods were considered practical for a launch abort and I have been unable to find any technical discussion of this in available official documents. The anticipated dimensions for the Pyramid were a length of 25ft 3in (7.69m), a height of 9ft 3in (2.81m), span 29ft 6in (8m) and wing area 332ft² (30.84m²). The best estimate of gross weight for this vehicle is approximately 4,122 lb (1,870kg), which indicates that the proposed Blue Streak launch vehicle would need to be significantly uprated, although the Armstrong Whitworth team avoided too much involvement in this area.

The Blue Streak Intermediate Range Ballistic Missile (IRBM) originated from a 1954 defence requirement outlining the delivery of a one megaton nuclear warhead with a mass of 2,990 lb (1,356kg) to a maximum range of 2,400 miles (3,862km). Partly derived from American technology, the development programme for this reduced size 'Atlas' missile was split between de Havilland who built the rocket and Rolls-Royce who provided the LOX/kerosene RZ 2 rocket engine. In the late 1950s a test site was established at Spadeadam Waste in Cumbria where the technology was examined in full, but no launches were undertaken. However, this location was seriously considered as a UK rocket launch site, although the idea was quickly rejected as politically undesirable. Another UK location briefly used to test rocket engines for the Black Arrow, Black Knight and Blue Steel rockets was High Down on the Isle of Wight. Some of the facilities there remain intact and plans exist to build a heritage centre around them.



A Blue Streak rocket undergoes handling trials at Spadeadam Waste in Cumbria. British Aerospace

Blue Streak's dimensions were length 61ft 6in (18.74m) and diameter 10ft (3.04m), and total launch weight was 198,000 lb (89,811kg). Apart from the length of time required to prepare for a launch Blue Streak performed well, but the rocket was finally scrapped due to the anticipated purchase of the American air-launched Skybolt missile. Although it was no longer being considered as a weapon, Blue Streak continued to be developed as a satellite launcher because there was reluctance in Whitehall to write off such a huge investment in new technology. The rocket was soon re-configured as a multi-stage vehicle called Black Prince (the Blue Streak Team at Farnborough actually started to consider a three stage satellite launcher based on Blue Streak in 1959) but this plan was eventually dropped for political reasons. Then the French and Germans became involved in building a new rocket based on Blue Streak as part of a project called the European Launcher Development Programme (ELDO). Unfortunately, the French and German second and third stages proved unreliable and, following a review in 1972, the Europa rocket developed by ELDO was abandoned. ELDO was re-structured as the European Space Agency (ESA) in 1974.

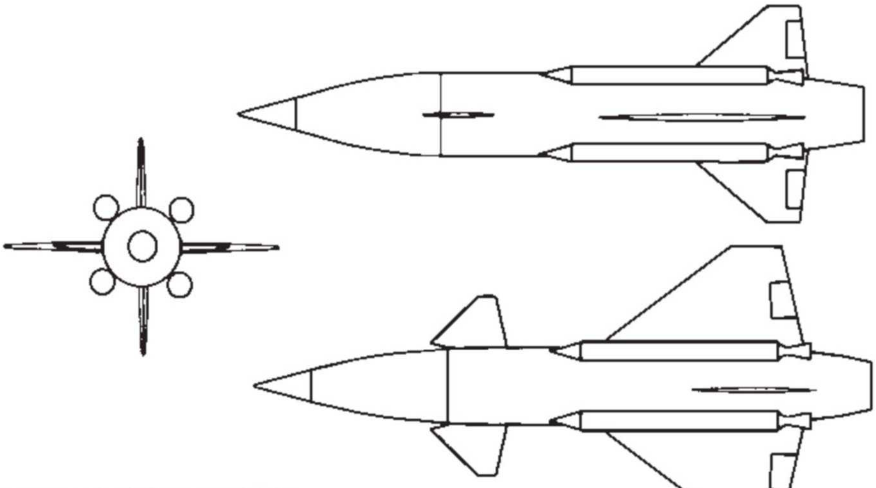
Returning to the manned Pyramid spacecraft, it would appear that the initial idea was to launch an unmanned test vehicle using a largely unmodified Blue Streak rocket on a brief sub-orbital flight. This would probably have taken place at Woomera in Australia. As the Pyramid spacecraft project progressed, it seems likely that a second stage would have been added, with the eventual use of strap-on boosters to increase performance further. By the late 1950s various wind tunnel models of the Pyramid spacecraft were being tested and, as the project evolved, a number of modifications were made to the design. A different tail configuration was briefly considered, then the short wings were removed and two large flaps were positioned at the back of the craft between the vertical stabilisers. Finally, a second design emerged. This had a rounded nose, the leading edges were more contoured and rounder and the top was flatter. A single flat control surface was attached to the rear of the vehicle and these changes were expected to address various issue of drag at subsonic speeds. But the Pyramid never progressed any further than a study. In 1960 Prime Minister Harold Macmillan cancelled the project, and in 1961 Nonweiler became Professor of Aeronautics and Fluid Mechanics at Glasgow University.

Advanced Blue Steel Projects

In 1954 a decision was taken in Whitehall to sponsor the development of a stand-off missile with a nuclear warhead for Britain's V-Bomber force. This was felt essential in the light of steadily improving Soviet air defences and, towards the end of that year, engineering studies began at Avro's Weapons Research Division at Woodford. The biggest decision was whether to use turbojet or rocket power for the weapon. Powered by a turbojet the missile would have a maximum speed of Mach 1.5 to 2 at 50,000ft (15,240m) and a range of 500 miles (800km). With rocket propulsion the performance increased to Mach 2.5 to 3 at 85,000ft (26,000m), but range might be seriously curtailed to 150 miles (240km) depending on the launch conditions.

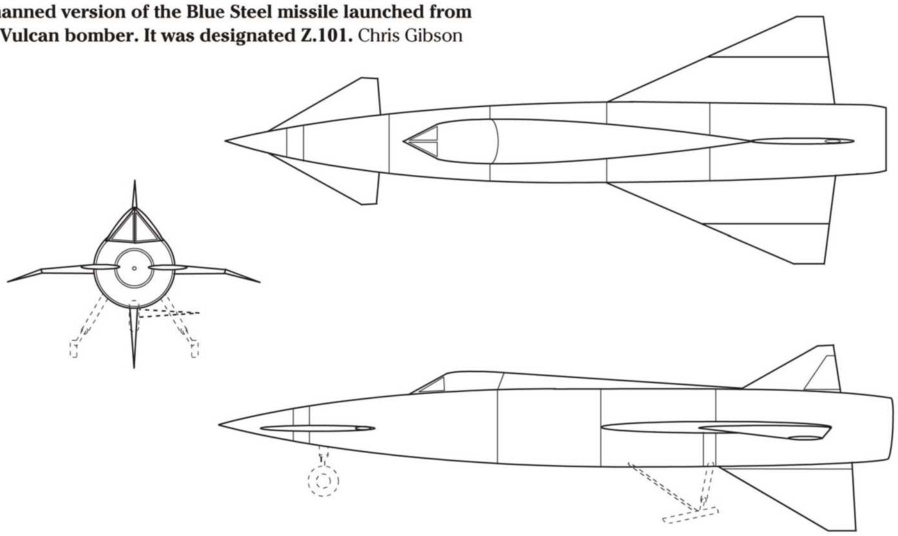
From the outset Avro's chief engineer Hugh Francis was convinced that rocket propulsion was essential if the RAF was to stay ahead of anticipated Soviet countermeasures and this recommendation was accepted. The overall design was strongly influenced by the USAF's Rascal missile and what became the Mk.1 Blue Steel had a length of 34ft 9in (10.6m), a span 12ft 11in (3.93m) and a launch weight of 15,000 lb (6,804kg). Initially the missile would carry the Green Bamboo high yield fission warhead, but this was superseded by Red Snow which was a thermonuclear design based on the American W-28 with a 1.1 megaton yield. An inertial guidance system built by Elliot Brothers was used which is said to have suffered initially with accuracy problems. An Armstrong Siddeley Stentor 101 rocket engine fuelled with hydrogen peroxide and kerosene propelled Blue Steel and in due course there were proposals to replace this with a ramjet engine, but these were never implemented.

The Victor, Valiant and Vulcan V-Bombers were all assessed for carrying Blue Steel, although the Valiant proved the least suitable due to a lack of clearance beneath the aircraft. In the case of the Victor it was necessary to remove Blue Steel's upper fin while positioning the missile below the aircraft, which meant that the Vulcan was the easiest of the three bombers when it came to modifying them for Blue Steel carriage. That said, two Valiants were adapted for use during trials and they made useful contributions to the programme, although no Valiant Blue Steel squadrons were formed. The weapon became operational in 1962 and remained in service until the beginning of the next decade.



The proposed Z.47 four-stage Flight Corridor Research Vehicle developed from the Blue Steel missile in 1959. Bill Rose

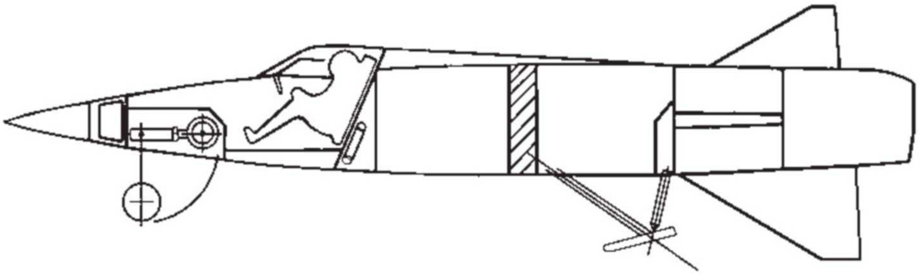
Avro Manned Blue Steel – a secret 1960s proposal for a manned version of the Blue Steel missile launched from a Vulcan bomber. It was designated Z.101. Chris Gibson



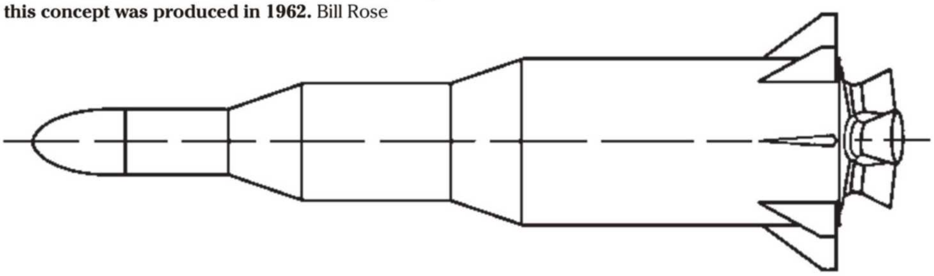
A number of extensively modified air-launched research versions of Blue Steel were proposed from early 1958 onwards. Designed to reach altitudes of 400,000ft (121km) or even higher, the first rocket in this series was called the Fringe Research Vehicle and was designated Z.47. It was powered by a Rocketdyne A-6 as its main engine, but used four strap-on Raven solid fuel boosters to improve launch performance and also had an Armstrong Siddeley Snarler fitted to the upper stage. The length of Z.47 is quoted as 38ft 5in (11.7m) with a finspan of 17ft (5.18). Further configurations were proposed for a number of different research purposes and one variant was designed to place a 300 lb (136kg) satellite into orbit. Anti-satellite (ASAT) and reconnaissance versions of Blue Steel were also studied, although these concepts didn't progress very far.

Unquestionably, the most interesting and unusual Blue Steel proposal was a manned version of the missile designated Z.101, which received serious consideration in late 1961. Seen as a UK rival to the American X-15 rocketplane, the Z.101 would carry a single pilot in a cockpit that replaced the large inertial navigation unit. The basic Z.101/35 would have a length of 35ft (10.66m) and a launch weight of 16,480 lb (7,475kg). This rocket vehicle would be air dropped at 55,000ft (16,764m) at a speed of around Mach 0.85 and was expected to attain about Mach 4.5, reaching an altitude of 290,000ft (88,392m).

The internal layout of the manned Blue Steel proposal. This illustration by Bill Rose is closely based on an original Avro drawing



The ultimate development of the Blue Steel missile was this three-stage satellite rocket air-launched from a modified Vulcan bomber. Known as Z.124, this concept was produced in 1962. Bill Rose



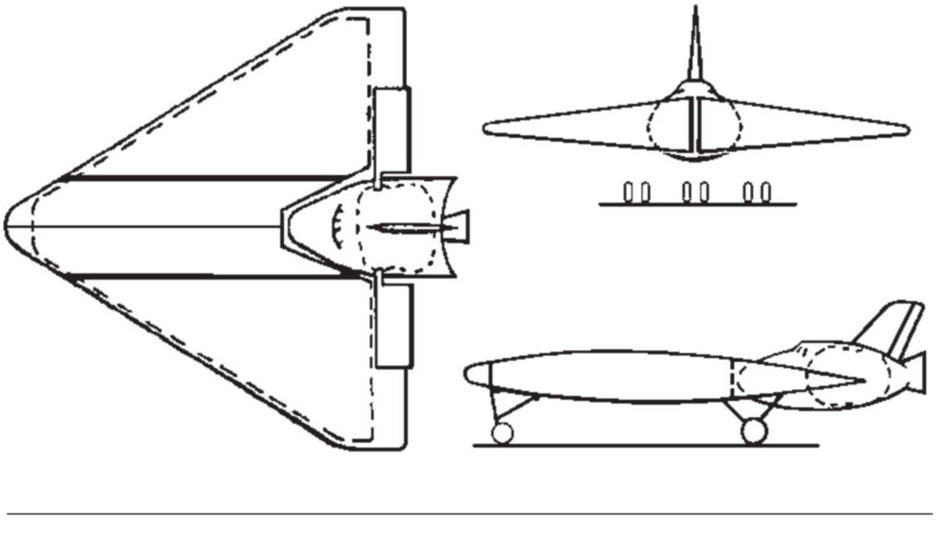
A slightly stretched version known as Z.101/38 with an enlarged kerosene tank would have had a length of 38ft (11.58) and a launch weight of 18,186 lb (8,249kg). This vehicle was to have been capable of Mach 5 and an altitude in excess of 300,000ft (91km). Z.101's rocket engine would utilise two chambers providing a fixed thrust of 22,000 lb (97.86kN) and a variable cruise chamber with a maximum thrust of 4,000 lb (17.79kN). After re-entry Z.101 would deploy a parawing for a controlled landing, which would be formed using a lowered nosewheel and skids. Each Z.101 would undertake ten missions from Woomera in Australia, travelling to two secretly selected landing sites about 300 miles (482km) down range. Both of these were dry clay pads and the preferred location was Lake Carringallana.

Several further Blue Steel options were considered, such as the multi-stage Z.102 designed for satellite launching which during 1962 evolved into a rocket called the Z.124 Vulcan Orbiter. Z.124 differed considerably from Blue Steel, it had a launch weight of 40,000 lb (18,143kg) and the ability to deliver a 400 lb (181kg) payload into a 345-mile (556.6km) orbit. Again, the Avro Vulcan's tall undercarriage would have made it possible to place Z.124 beneath the aircraft without too much difficulty. None of these concepts progressed much further than the drawing board, although there was a later proposal made by engineers at Bristol Siddeley to use the supersonic BAC TSR.2 strike aircraft as a launch platform for a three-stage ramjet/rocket vehicle capable of delivering a 400 lb (181kg) load into a low orbit. Needless to say this interesting project was also abandoned at an early stage.

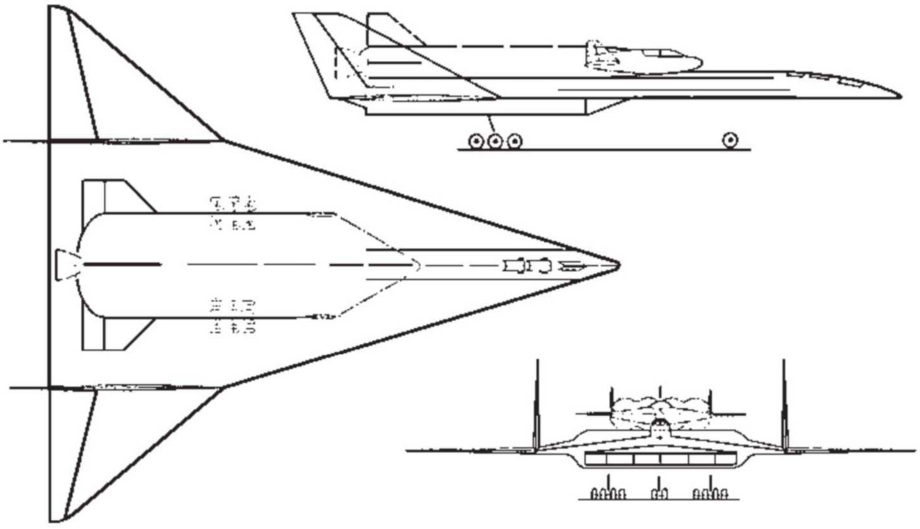
British Aircraft Corporation (BAC) Delta-Winged Spaceplane

Although the Armstrong Whitworth Pyramid was cancelled in 1960, the idea of developing a small British spacecraft continued to generate low-level official interest and alternative studies were undertaken at the British Aircraft Corporation's Preston Division.

Heading the project was Geoffrey F Sharples who had been employed by English Electric during the 1950s as an undercarriage specialist and was involved in the Lightning interceptor's development. After English Electric was absorbed into the BAC conglomerate in 1960, Sharples was assigned to spacecraft design and he proposed a two-stage orbital vehicle that could take-off and land on a conventional runway. The concept was quite unusual because the first stage took the form of a large delta wing that provided lift and fuel for the second smaller stage that was carried at the rear of the wing and housed the vehicle's propulsion unit. This compact spacecraft contained a pressurised cabin for the pilot, a cluster of rocket engines, fuel tanks and a small payload bay. It would be fitted with a single tailfin for control after re-entry and two short extendable wings that would act as control surfaces during ascent



An unusual early BAC concept for a large two-stage delta winged spacecraft. The delta wing is little more than an aerodynamic fuel tank carrying a small orbital spacecraft at the rear.
BAC via Bill Rose



A Mach 4 double delta turbo-ramjet aircraft developed by BAC at Preston as the first stage in an orbital spacecraft proposal. Bill Rose but closely based on BAC artwork

and allow a controlled glide to the landing location. It was also suggested that these wings could contain solar panels to generate electrical power or might be used as heat radiators while the vehicle was in orbit.

The spaceplane would make a conventional runway take-off using a jettisonable undercarriage trolley and the delta-wing first stage would be disposable. The upper stage containing the propulsion system would be fully re-usable and able to return to base, making a runway landing on a tricycle undercarriage. It was proposed to equip the spacecraft with systems that would allow it to be flown by remote control. Little is known about the intended use of this vehicle, which appears to have been military. Missions would have included reconnaissance and perhaps anti-satellite (ASAT) operations, although no details can be found which provide estimates for payloads. This particular project was abandoned in the early 1960s and interest switched to more conventional ideas for horizontally launched spacecraft systems.

RAE Space Fighter

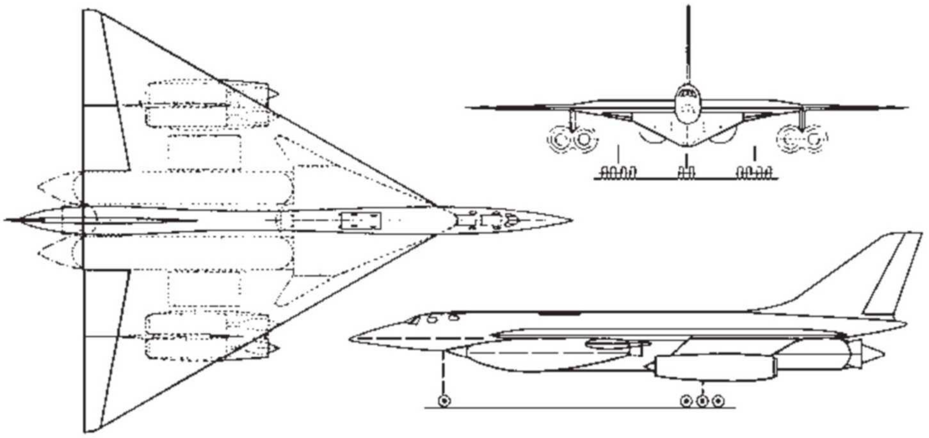
At the start of the 1960s the Ministry of Aviation (MoA) began to take a serious interest in the Boeing X-20 spaceplane, which was under development for the USAF. Utilising boost-glide principles, the X-20 would initially be a long-range sub-orbital vehicle but it could be given a full orbital capability in the form of an upgrade to the launch system. The USAF anticipated using Martin Titan II and Titan III boosters to launch the X-20 but also considered several air-launched options. In due course the X-20 would become a military vehicle capable of performing a range of different tasks and British officials viewed this project with considerable interest and a degree of envy. However, launching rockets from the UK was a problem and the British wanted a system that could be operated from RAF runways. Consequently, the Royal Aircraft Establishment (RAE) was requested to begin a series of studies often referred to as the Orbital Fighter Proposal.

In September 1962 the brilliant mathematician Prof Michael James Lighthill (1924-1998), who became Director of the RAE in 1959, revealed to a group of aviation journalists that studies were taking place to determine the viability of a large Mach 7 aircraft for military applications. It would be capable of reaching altitudes of 120,000 to 150,000ft (36,500 to 45,700m) and had a range of about 4,000 miles (6,400km). Lighthill went on to suggest that this ramjet-powered hypersonic aircraft might be used to launch a smaller spaceplane capable of achieving Mach 12 to 14 at an altitude of 180,000ft (55km); an eventual booster upgrade would also allow orbital flights to be made. Further estimates for the RAE's proposed manned hypersonic launcher suggested that the release altitude for the spacecraft and booster would probably take place at about 75,000ft (22,860m). The spaceplane was a one-man lifting body vehicle which showed similarities to the Boeing X-20, although it was slightly smaller. It would be propelled by an expendable rocket booster that provided a high-altitude or, ideally, an orbital capability.

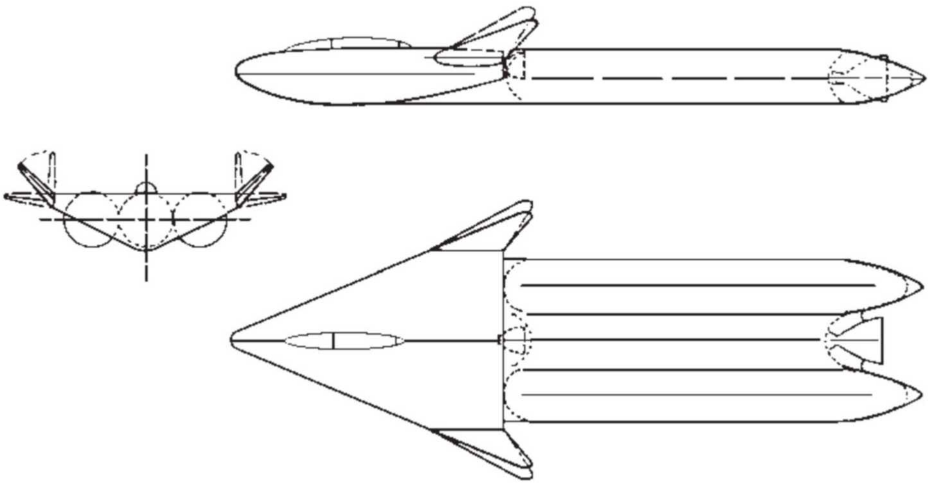
The spaceplane would undertake long-range reconnaissance missions across the Soviet Union, conduct ASAT operations and perhaps launch small satellites, while the launcher might be developed into a high performance bomber or reconnaissance aircraft. The study was eventually expanded to include BAC at Preston, who was secretly contracted by the MoA (Ref: KD/2X/2CB7(c)) to produce a wider study of hypersonic aircraft and space vehicles. This was completed by the end of 1963 and submitted to the MoA in January 1964. The initial BAC proposal was for a large two-man delta winged high-performance aircraft which would act as the first stage of a spacecraft launch system. It would have further potential for development as a military or transport vehicle.

This concept was designated EAG 4396 and took the form of a double delta with 73° and 50° sweep angles. Exact dimensions are uncertain but it was expected to have a length of approximately 160ft (48.76m) and an overall wingspan of about 130ft (39.6m). EAG 4396 would be powered by six Rolls-Royce or Bristol Siddeley turbo-ramjet engines in a ventral pack and they would run on conventional aviation fuel. The Preston team set out with the aim of designing an aircraft capable of hypersonic speed, but existing propulsion technology and the availability of suitable materials for the aircraft's construction brought about a decision to limit maximum speed to Mach 4, with a ceiling in the region of 90,000 to 100,000ft (27,500 to 30,500m). Used as a launch vehicle the gross take-off weight was calculated to be 500,000 lb (226,800kg) and the optimal release altitude was 84,000ft (25,600m) at an angle of about 20°. Wind tunnel models are known to have been tested and a simpler straight delta wing was eventually considered the best solution; most of the airframe would be constructed in titanium alloy.

Many different launch vehicle configurations were considered during this study and a number of existing aircraft were examined for possible use. These included the Vickers VC-10 airliner and Avro Vulcan and US Convair B-58 bombers, although each of them would have required extensive modifications to serve in this role. The B-58 emerged in a very positive light, possibly because the British designers were aware that this aircraft had been considered as the launcher for a secret Mach 6 spyplane or a ballistic missile. As a consequence, the B-58 was chosen as the starting point for a new BAC launch aircraft which was assigned the development reference EAG 4409. Looking very similar to the B-58, but utilising underwing twin-engine nacelles and an uprated undercarriage, the



A Mach 2.2 aircraft proposed by BAC in the early 1960s to act as the first stage in an orbital spacecraft system. Bill Rose but closely based on original artwork



An early 1960s BAC spaceplane and booster stage proposed for use with the Mach 2.2 launch aircraft. Bill Rose but closely based on original artwork

two-man supersonic EAG 4409 would carry the spaceplane and booster beneath its fuselage. This was considered preferable to carriage on the back of an aircraft, which was the only option available for the EAG 4396 because of the engine layout and ventral air intakes. EAG 4409 would only reach a maximum speed of about Mach 2.2, but it was realised that the reduced launch speed (compared to EAG 4396) was not a major issue. This simpler design allowed a greater weight to be carried and, therefore, the payload to orbit capability was slightly improved. In fact, as the study progressed, a Mach 0.9 version of this aircraft known as EAG 4412 was also proposed.

BAC studied several concepts for spaceplanes but the favoured design appears to have been fairly closely based on the original RAE Space Fighter. This took the form of a small lifting body vehicle designated EAG 4413, which was fitted with variable position tailfins, a reaction control system, an X-20-style heatshield over the cockpit windshield, an ejection capsule for one or two crew members and skids for horizontal landing. The expendable second stage booster used to lift the EAG 4413 spaceplane into orbit comprised little more that two side-by-side fuel tanks containing liquid hydrogen and LOX, plus a single Rolls-Royce rocket engine.

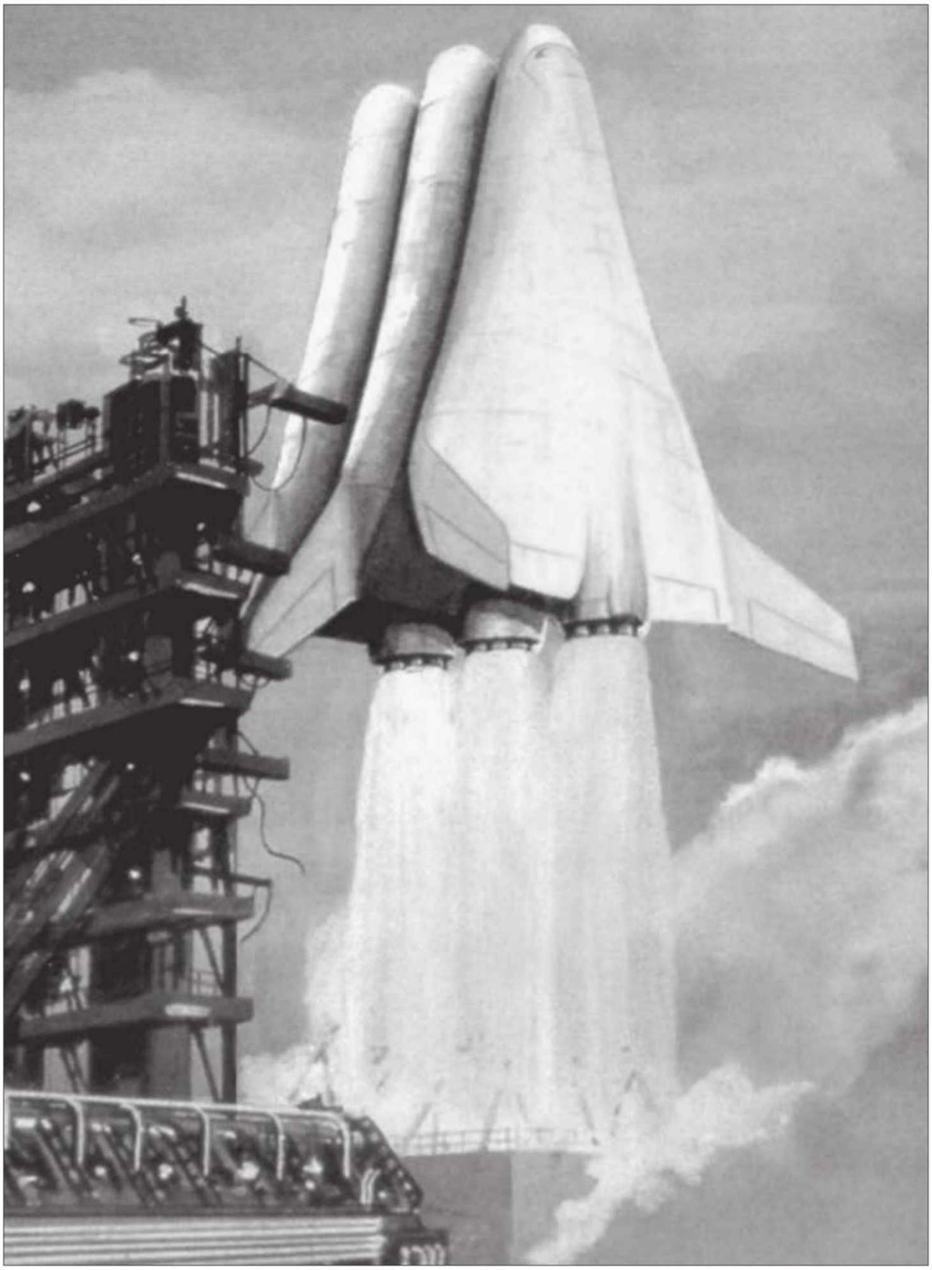
Single cylindrical boosters were also examined but the side-by-side configuration was regarded as the better solution for air-launch and some versions utilised stabilising fins (depending on the carrier aircraft and launch method). High inclination polar orbits were specified but payloads would have been seriously limited for these missions. The exact military role envisaged for this spaceplane is not entirely clear, although satellite inspection and possible destruction was the prime consideration. Orbital reconnaissance and the ability to launch small satellites would also have been examined. The study suggests that no overwhelming technical challenges were envisaged to implement this project. Nevertheless, it would have been very expensive and of dubious value, which undoubtedly explains why it progressed no further.

The UK home for the RAF's spaceplane was going to be a brand new facility at Brancaster Bay in North Norfolk, but it was recognised that a second facility in an equatorial region would be highly desirable. During the late 1950s Brancaster Bay had been secretly earmarked as a Blue Streak missile base and a major test facility for rockets, and the idea remained popular in Whitehall because of the convenient distance from major UK aerospace facilities. There are no significant landmasses between Norfolk and the Arctic (test missiles would have been fired towards the North Pole), so this location appeared to be a good choice. But nowhere in Britain is well suited to rocket launches and the plans for Brancaster Spaceport were finally dropped in 1966 because of the growing number of oil and gas platforms in the North Sea that would be put at risk.

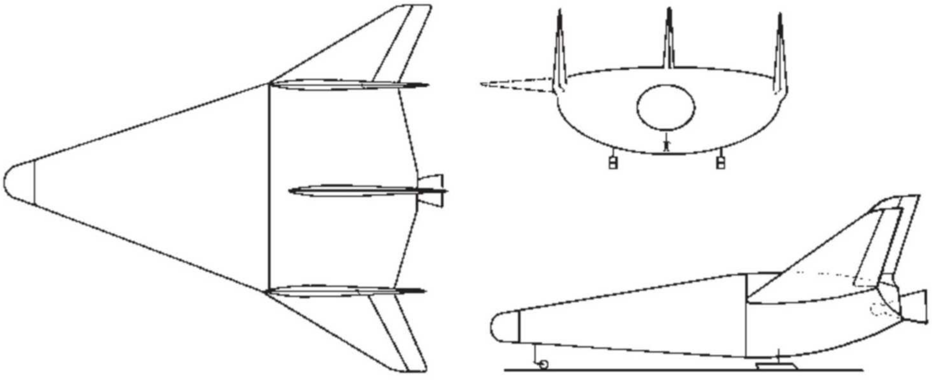
At least, that was the official line given to ministers, but Britain's IRBM programme had come to an end with the cancellation of Blue Streak and subsequent hopes to exploit this technology for commercial purposes failed. The USAF's X-20 was also scrapped at the end of 1963 and this must have sent a message to the UK Government about the risks of undertaking such an ambitious project. It was probably all for the best as there simply wasn't enough money available for this kind of high-status defence project in the 1960s.

MUSTARD

Following its hypersonic and spacecraft projects, BAC's Preston Division began work on a fresh set of Government funded studies to examine the possibility of developing a fully re-usable, cost-effective manned spacecraft that would be capable of fulfilling a number of civil and military roles. The military uses for this system were the re-supply of a 10-man orbital space station (of which details are unknown), orbital reconnaissance, satellite inspection and near space control. A single-stage-to-orbit (SSTO) vehicle was considered technically too demanding, but there was an interesting new idea under consideration using several fully re-usable fly-back boosters. This project was co-ordinated by the company's chief aerodynamicist Thomas



An illustration showing the most favoured launch configuration for the MUSTARD space vehicle system. BAC



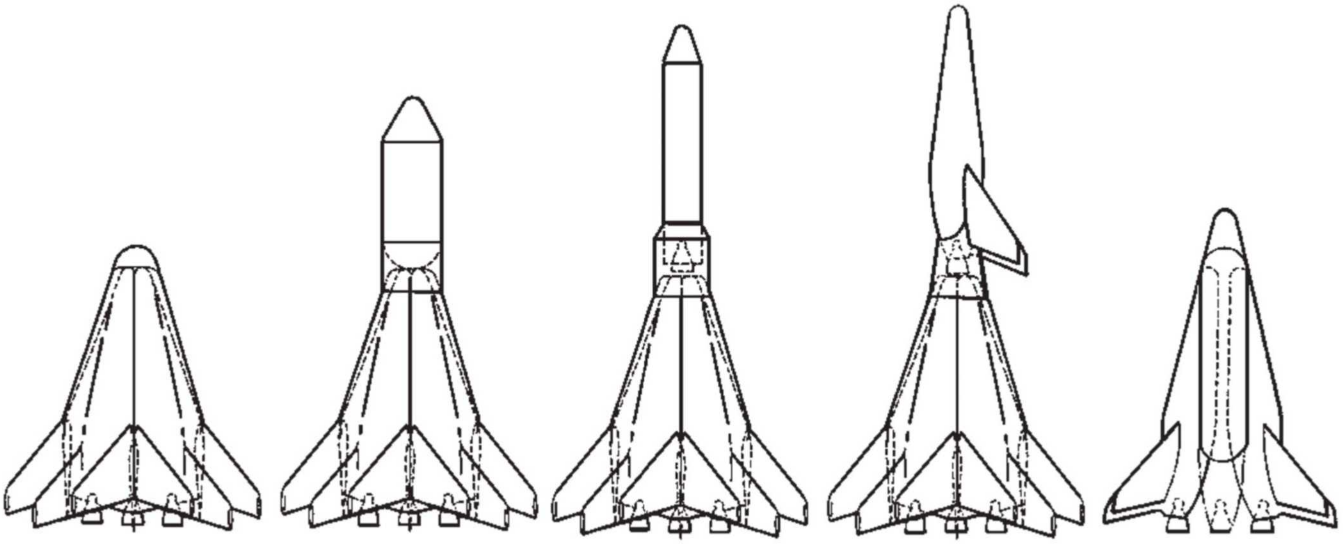
An early design for the MUSTARD spaceplane. This vehicle is an evolution of earlier lifting body studies and utilises an additional stabilising fin. BAC via Bill Rose

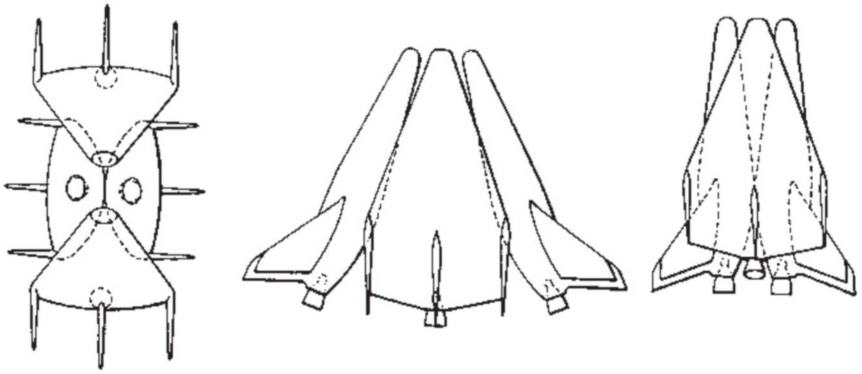
William Smith, who was assisted by Gerald Walley and Robert Wilson. Drawing on some of the design work undertaken during the Space Fighter programme, and various American lifting body concepts, the new project was given the name Multi-Unit Space Transport And Recovery Device or MUSTARD.

This system would use a stack of similar spaceplanes that were bolted together and launched vertically. Separation would take place at high altitude and one of the vehicles would continue to climb into orbit under its own power, while the others returned to base to make conventional runway landings. Many different launch configurations were examined using two vehicles upwards. One heavy-lift concept proposed the use of six spaceplanes assembled around an extra fuel tank and with a large rocket stage on top.

However, the final launch configuration for a routine orbital mission was three similar vehicles in a stack or triangular format, which was regarded as the best general purpose arrangement for modest orbital operations. (If the project had been funded MUSTARD would have used the three-vehicle configuration – at least to start with.) The key feature of this system was that, during ascent, the supporting vehicles acting as boosters would transfer fuel to the vehicle travelling into space. At an altitude of approximately 200,000ft (61,000m), when approximately two thirds of the launch fuel had been consumed, separation would take place. Now the fully fuelled upper stage MUSTARD vehicle, carrying a payload of approximately 5,000 lb (2,267kg), would continue to Low Earth Orbit. According to BAC this unusual system of transferring fuel from one vehicle to another during ascent could eventually allow missions to the Moon.

The MUSTARD boosters, either manned or unmanned, would return to base to complete conventional runway landings. It was decided that the ideal way to make a controlled landing would be with the assistance of retractable turbojets that ran on liquid hydrogen drawn from the vehicle's main fuel tank. Smith and Walley believed that all of the MUSTARD vehicles should be of identical design and interchangeable and, with production costs in mind, one common airframe would be used and one standard propulsion



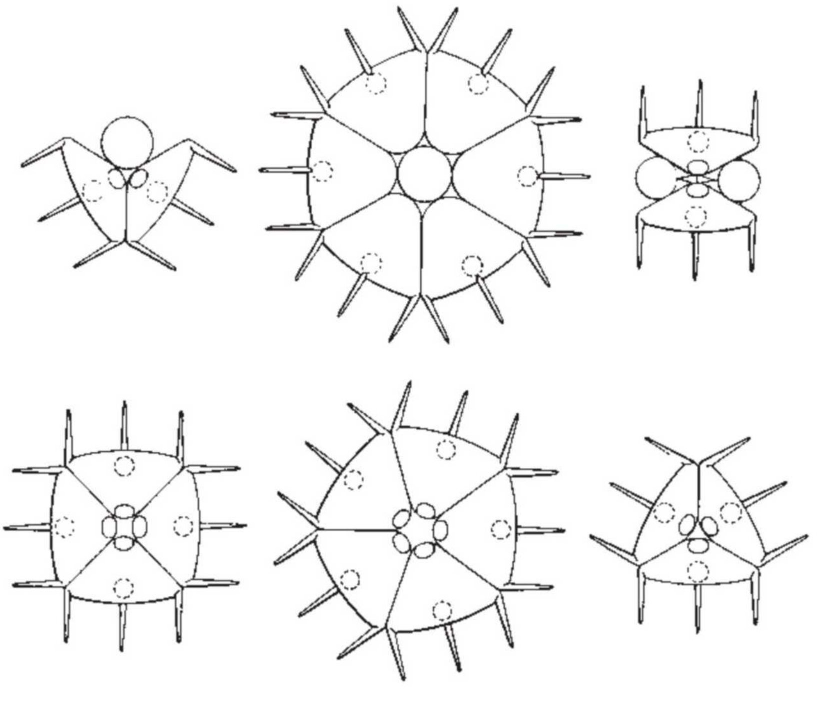


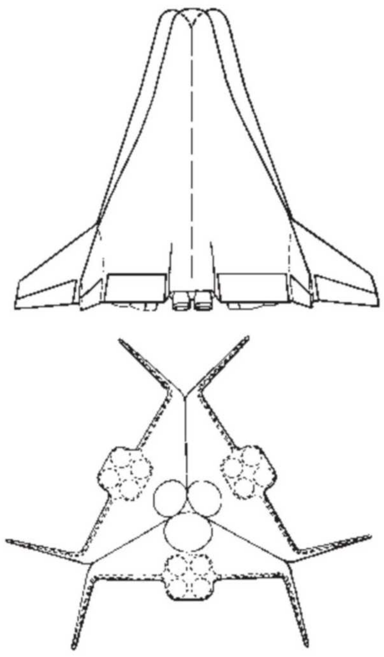
Above: **Various MUSTARD launch configuration proposals for different missions.** BAC via Bill Rose

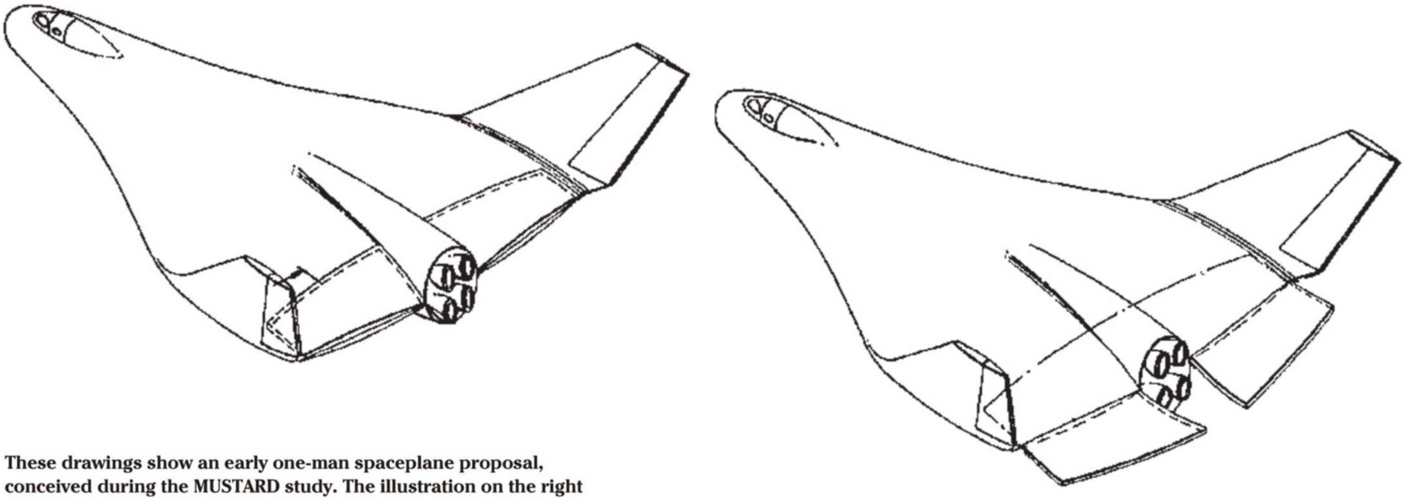
Left: **A four-vehicle proposal for the BAC MUSTARD study.** BAC via Bill Rose

Bottom left: **Various MUSTARD launch configurations showing from two to six vehicles.** BAC via Bill Rose

Bottom right: **A three-vehicle launch configuration for the MUSTARD spaceplane system.** BAC via Bill Rose







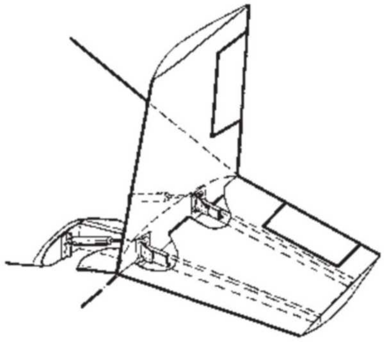
These drawings show an early one-man spaceplane proposal, conceived during the MUSTARD study. The illustration on the right shows the control surfaces in extended position. BAC via Bill Rose

unit selected. However, it was also accepted that the MUSTARD vehicles used as boosters would not require the same amount of heat shielding as the space vehicle and this would have permitted some cost cutting.

The spacecraft went though numerous changes as the lifting body shape evolved, and in the earliest technical literature it was often referred to as a flying wing design. The spacecraft was initially expected to carry a crew of two or possibly three, with the payload housed in an upper bay behind the crew compartment. In space MUSTARD would be controlled by gimballing the rocket engine(s) and a small reaction jet system. The eventual configuration for the MUSTARD spacecraft bore quite a resemblance to the upper stage of a 1963 Douglas proposal for a fully reusable spacecraft system called Astro. The similarities ended there because the Douglas concept would have been launched into space on top of a slightly larger lifting body booster stage. But it is possible that some exchange of technical information took place between Douglas and BAC during this period. MUSTARD's two upright control surfaces could be turned outwards to provide additional lift following re-entry by increasing the aspect ratio, shifting the aerodynamic centre rearwards and increasing the lift/drag ratio.

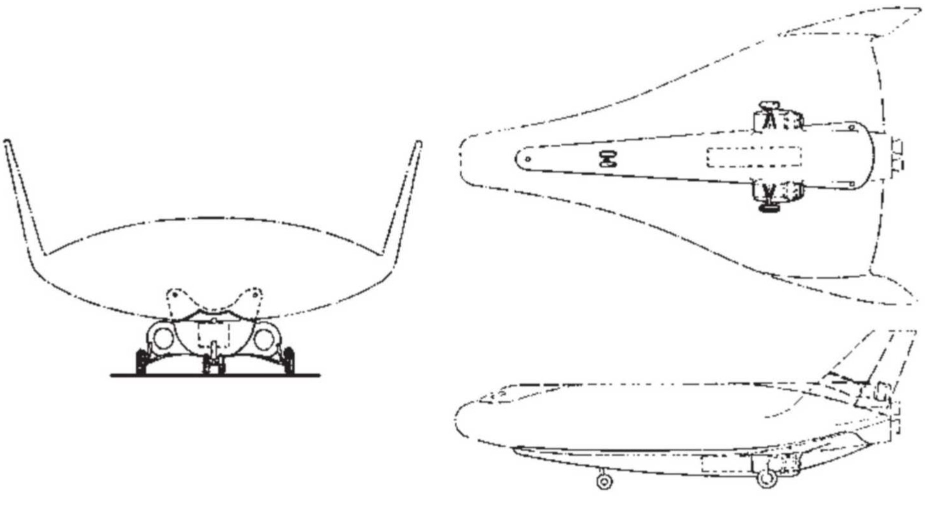
Specifications for the MUSTARD space vehicle are only approximate and the following figures appear to relate to the definitive concept that appeared in early 1966. The length of the MUSTARD spaceplane was set at 98ft 6in (30m), it had a span of 65ft 6in (20m), gross mass was estimated to be 313,462 lb (142,184kg) and the empty vehicle would weigh 54,990 lb (24,943kg). Multiple engines were considered but the preference was a single rocket engine burning liquid hydrogen and liquid oxygen. This would produce an expected thrust of 485,017 lb (2157.4kN) and an Isp of 405 sec; burn time would be 215 seconds. The combined take-off weight would be 935,740 lb (424,444kg) and the lift-off thrust from all three vehicles would be 1,077,818 lb (4,794kN).

The spacecraft's airframe and upper surfaces would be mainly fabricated from titanium and the underside would be made from nickel alloy panels. This was possible because the vehicle would experience lower re-entry heating rates than the US Shuttle. Steel and titanium would be used for the LOX and LH2 storage tanks inside the vehicle. Separate forward and aft payload bays were a feature of the final design and, although this was a less than ideal arrangement, the locations were probably dictated by fuel storage

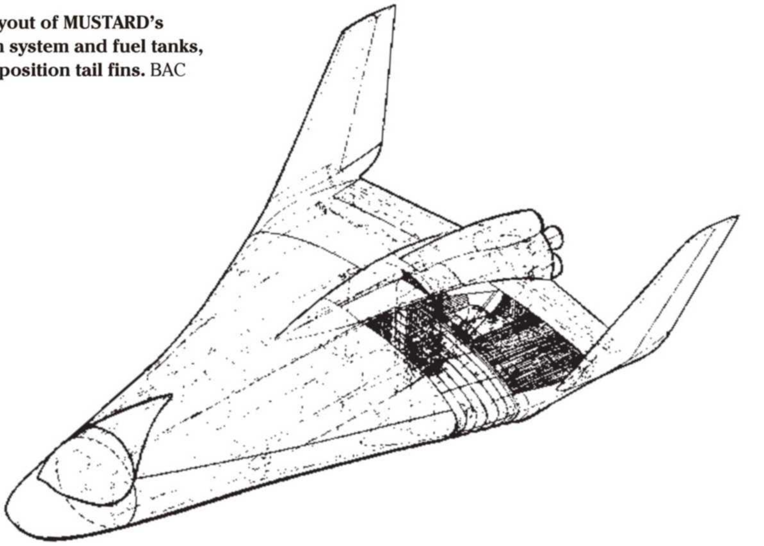


Above: **Detail of variable angle control fins favoured on most of the lifting body spaceplane designs considered for MUSTARD.** BAC via Bill Rose

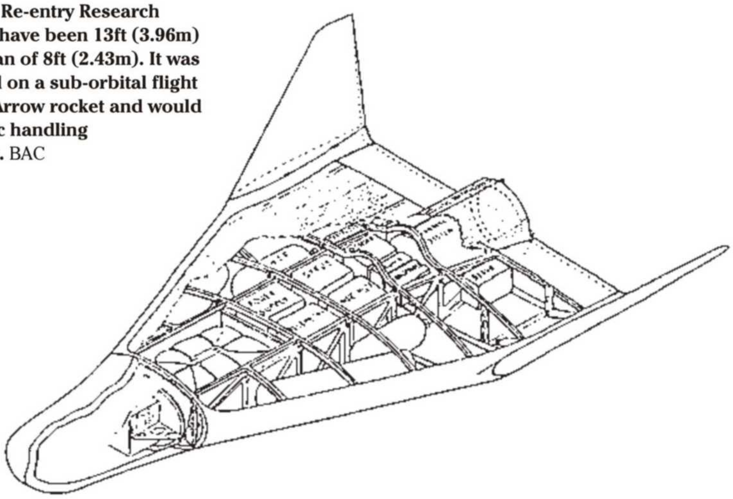
Below: **Dedicated MUSTARD undercarriage and propulsion unit, allowing brief jet powered flights between locations as a conventional aircraft.** BAC via Bill Rose



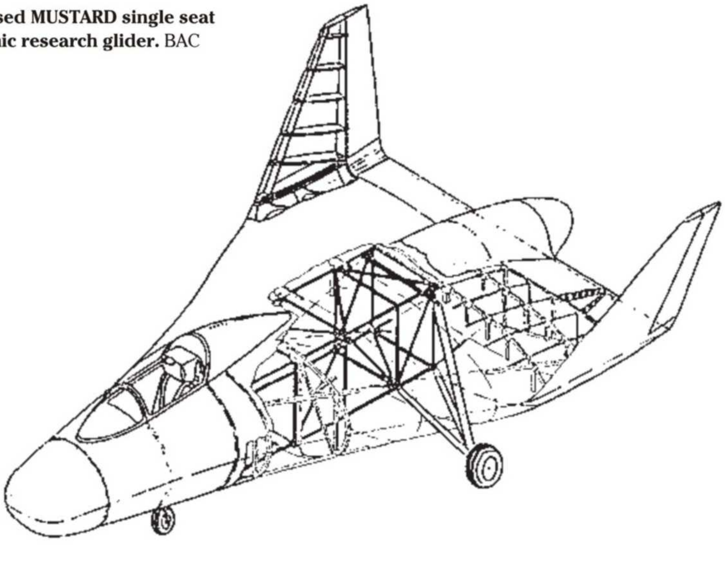
Internal layout of MUSTARD's propulsion system and fuel tanks, with fixed position tail fins. BAC



The MUSTARD Re-entry Research Vehicle would have been 13ft (3.96m) long with a span of 8ft (2.43m). It was to be launched on a sub-orbital flight using a Black Arrow rocket and would test hypersonic handling characteristics. BAC



The proposed MUSTARD single seat aerodynamic research glider. BAC

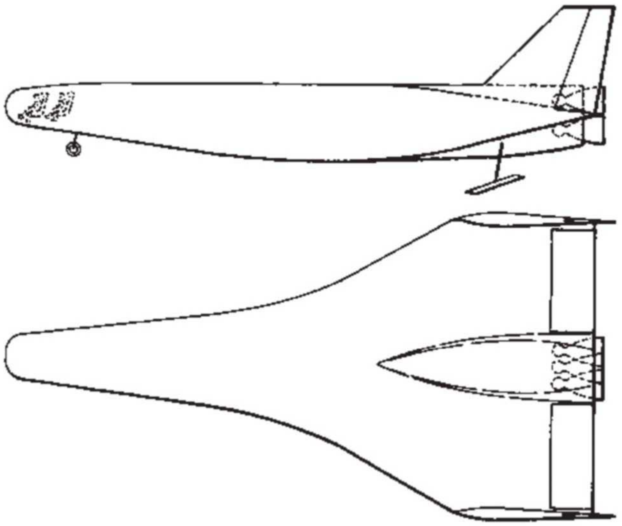


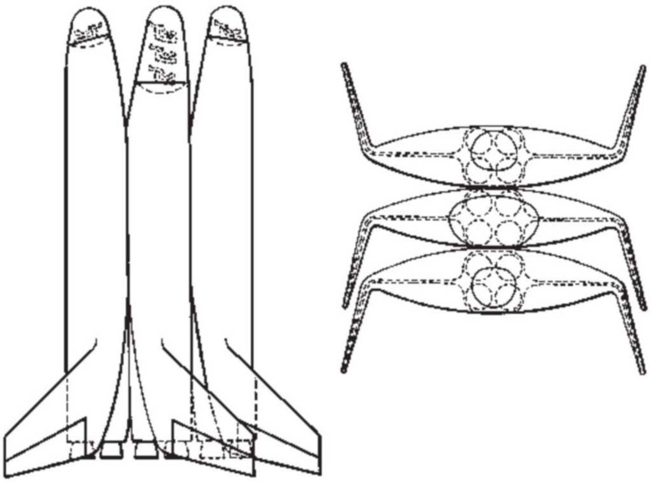
and weight distribution requirements. The main cockpit would accommodate two crew members and a lower linked cabin area would be used to carry additional personnel. The booster vehicles would have been almost identical to the spaceplane but utilised a much simpler one-man cockpit and had no payload bays.

One interesting part of the MUSTARD system was a specially constructed trolley for runway take-offs and landings. This would allow the vehicle to make short flights between manufacturing or maintenance facilities and launch sites, while also proving an essential item in the event of an emergency landing at an alternative airfield where its attachment would allow MUSTARD to be flown back to base. The trolley unit took the form of an aerodynamic fairing containing jet engines and its own fuel supply. Drawings show a fixed undercarriage and full control of this module would come from the spacecraft's cockpit. It is also possible that the trolley might have been used for some ground handling operations. All MUSTARD vehicles would be equipped with low-powered onboard jet engines and a lightweight retractable tricycle undercarriage, but both were unsuitable for transfer flights.

From an early stage in the study it was planned to build a 13ft (3.96m) long model of the MUSTARD spaceplane which could be launched on a sub-orbital flight using a Black Arrow rocket. There was also a request to assemble a manned lifting body glider for research purposes. This 26ft (7.92m) long aircraft would be fabricated from a welded tubular steel framework covered in plywood, it would have a fixed tricycle undercarriage and there was provision to fit a small rear-mounted propulsive unit at a later date. It was also determined that a single MUSTARD vehicle could be launched vertically to high altitude during the development phase and later for training purposes. While the MUSTARD project never reached the construction stage, it is known that several wind tunnel models were tested.

Extraordinarily, in 1965 the Convair Division of General Dynamics at San Diego developed a spaceplane concept which bore many striking similarities to MUSTARD. This study was undertaken for the USAF's classified Integrated Launch & Re-entry Vehicle (ILRV) programme (AF33-615-67-C-1885), which examined the possibility of developing a fully re-usable spaceplane system. Initially designated T-18, the Convair spacecraft differed from MUSTARD in having folding wings for use after re-entry. However the launch method was very similar, using three identi-





Above left: **One of the various MUSTARD concepts illustrates the proposed positions of the nosewheel and skids to facilitate a horizontal landing.** BAC via Bill Rose

Above right: **MUSTARD three-vehicle assembly for launch.** BAC via Bill Rose

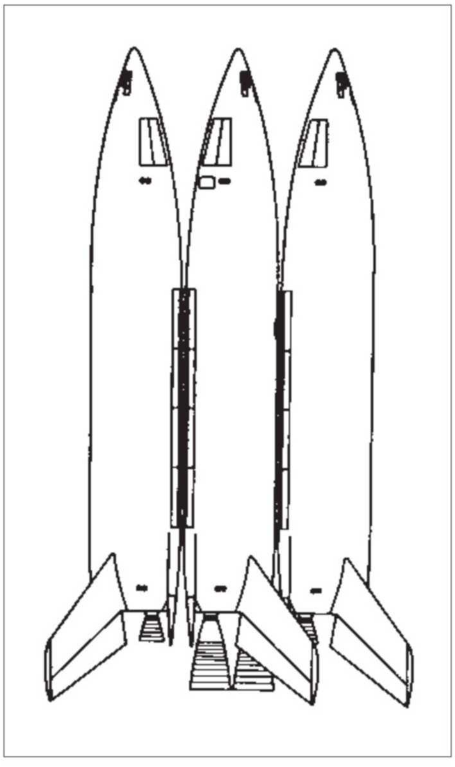
Below left: **In 1965 the Convair Division of General Dynamics produced a fully re-usable spacecraft design with many striking similarities to MUSTARD.** Convair

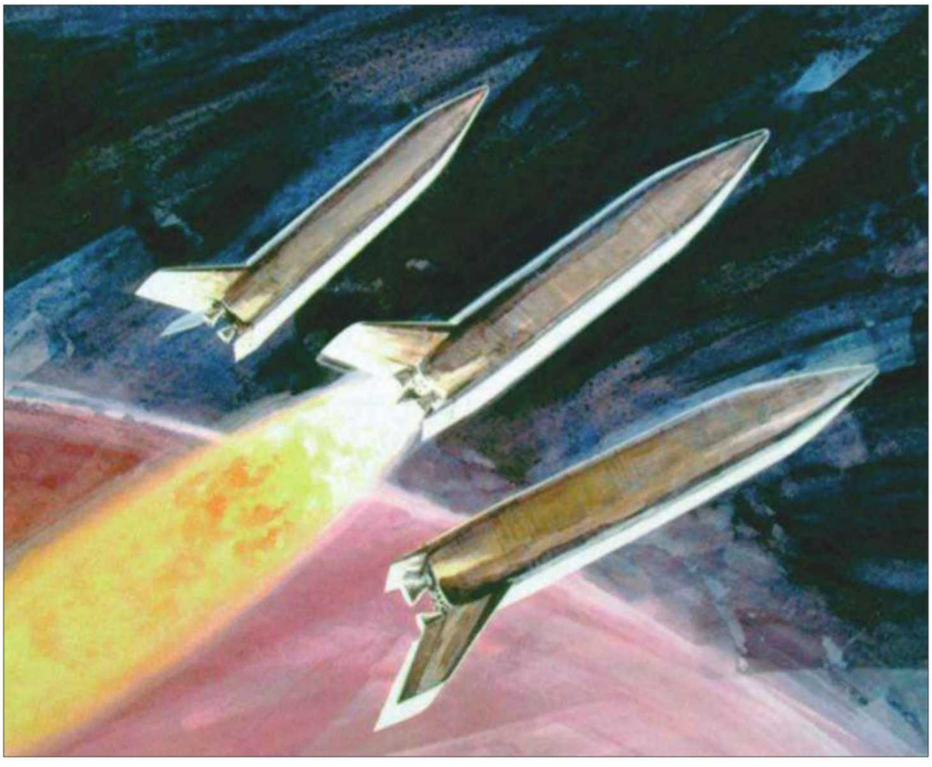
Below right: **Artwork depicting the Convair three vehicle space system separating at high altitude.** Convair via Bill Rose

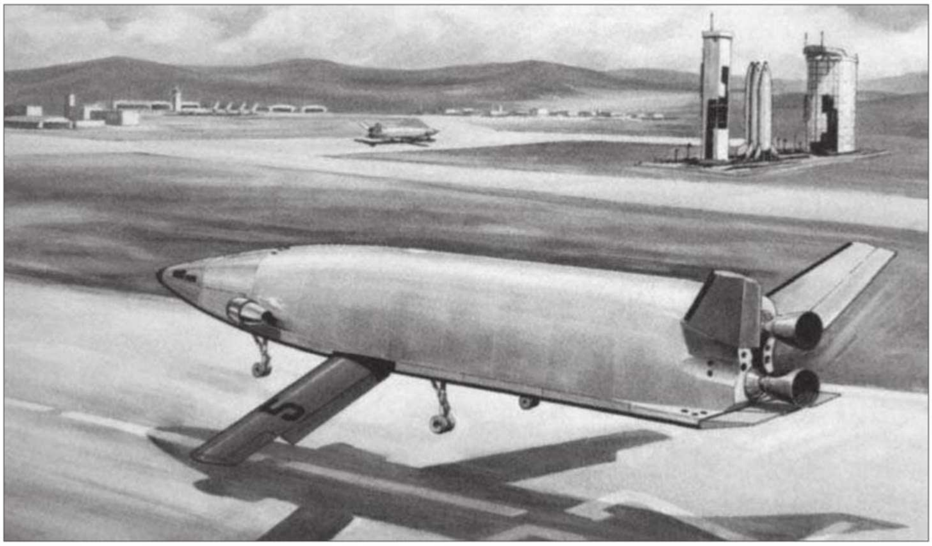
cal vehicles with fuel transfer taking place during ascent. These Convair studies continued until the end of the 1960s and evolved into the FR-3/4 designs. Some years later there were denials that Convair or BAC had any idea what the other company was doing, but it is hard to dismiss the possibility that some unacknowledged technology transfer took place. Towards the end of the 1960s the MUSTARD project was shelved. Although somewhat unconventional, the design was innovative and might have been made to work if sufficient money had been spent on it.

Hawker Siddeley TSTO Concept

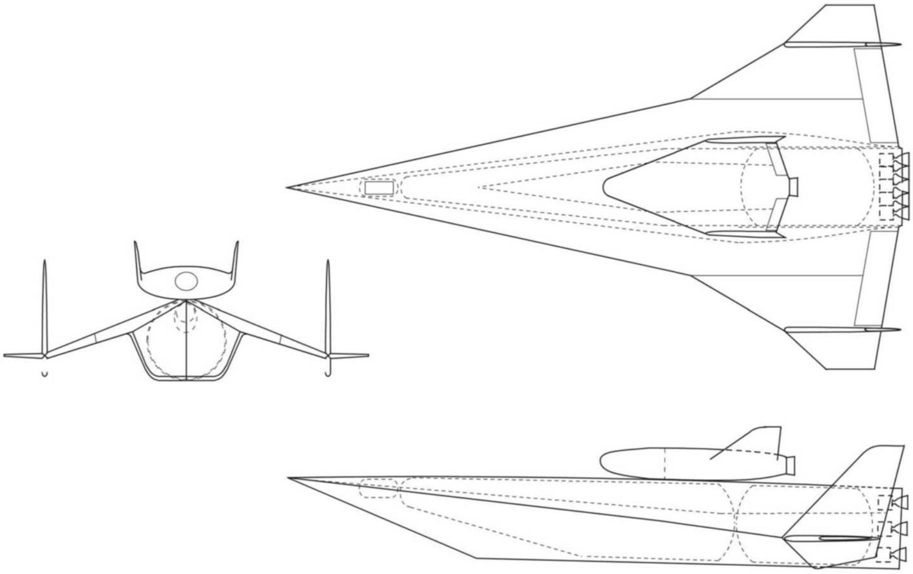
In 1964 BAC's UK rival Hawker Siddeley Aviation (HSA) at Kingston began to study a fully re-usable Two-Stage To Orbit (TTSO) system that would be capable of operating from a conventional runway within Europe. The Advanced Projects Group led by Hugh Francis was following on from research undertaken by the RAE, and responding to the Junkers Raumtransporter which had been conceived by Eugen Sänger at the start of the 1960s. This was seen as an important study within the company because HSA had just



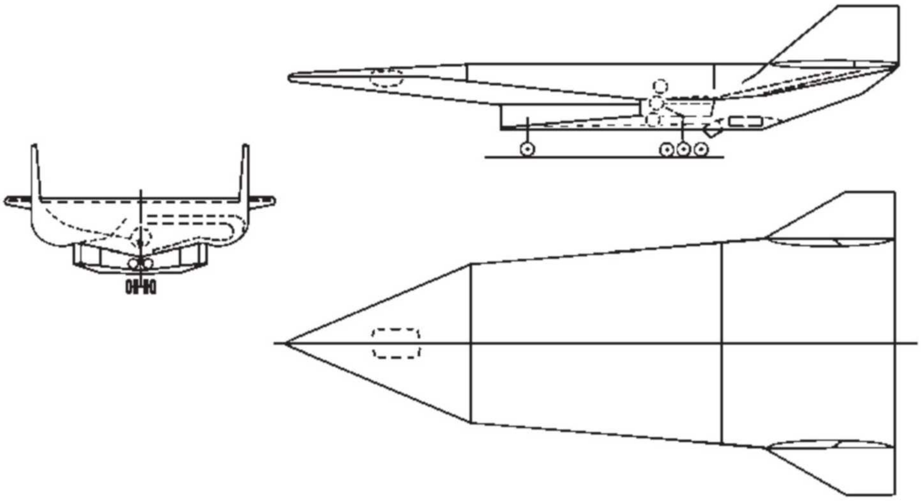




The Convair T-18 Triamese spacecraft returns to make a horizontal runway landing. Convair



Alternative Hawker Siddeley proposal for a double delta vehicle capable of hypersonic performance to be used to launch an orbital spacecraft. Chris Gibson

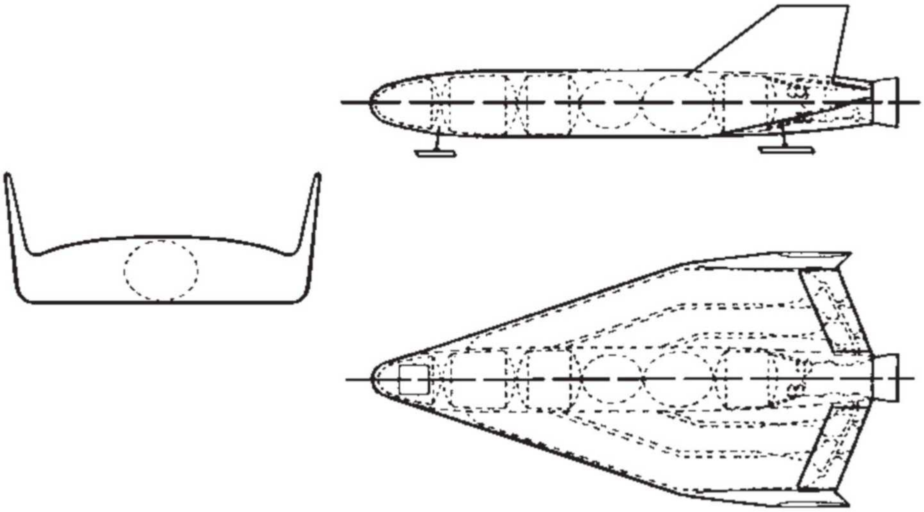


Another Hawker Siddeley proposal for an air-breathing hypersonic spacecraft launch vehicle. British Aerospace

made an arrangement with SNECMA and Junkers to form Eurospace and needed to retain its status as a high-tech company. The first manned stage of the new system was a very large delta-shaped vehicle with an estimated overall length of 200ft (60.9m), a span of 121ft (36.8m) and a height of 41ft (12.5m). Estimated gross weight would be approximately 400,000 lb (181,000kg) and the aircraft would be equipped with a substantial tricycle undercarriage.

There is confusion about the propulsion system for this vehicle, probably because several alternative systems were considered. One suggestion was to use six liquid hydrogen/liquid oxygen-fuelled rocket engines, but there were proposals as well to use turboramjets capable of propelling the vehicle to Mach 5.5, supplemented by scramjets (when technically feasible) that could take it to Mach 12. Because this was just a study these different possibilities could be considered, but the HSA design team was aiming for a maximum speed of about Mach 6.5 with a proposed ceiling/separation point of between 150,000 and 250,000ft (45,700 and 76,000m). Further developments of this vehicle might have been a long-range hypersonic reconnaissance vehicle or bomber with Nonweiler waveriding characteristics.

The lifting body upper stage was somewhat bigger than the earlier RAE concepts. It was powered by a single liquid fuel rocket engine capable of delivering the craft into a low orbit with a payload of approximately 8,000 lb (3,628kg). The dimensions of the Hawker Siddeley spaceplane were length 57ft (17.4m), span 34ft 6in (10.5m) and gross weight 89,900 lb. Two vertical stabilisers and trailing edge control surfaces were fitted for atmospheric use and the vehicle would be flown by a crew of two or by remote control. Hawker Siddeley and the RAE had taken a keen interest in waveriders throughout the 1960s. While the RAE sponsored tests of at least one small rocket launched waverider at Woomera and undertook wind tunnel studies, Hawker Siddeley developed plans that were optimistic in the extreme. It proposed a highly uprated multi-engined Blue Streak booster with a



Right: **Hawker Siddeley Upper stage orbiter, designed for use with the horizontal take-off hypersonic vehicle.** British Aerospace

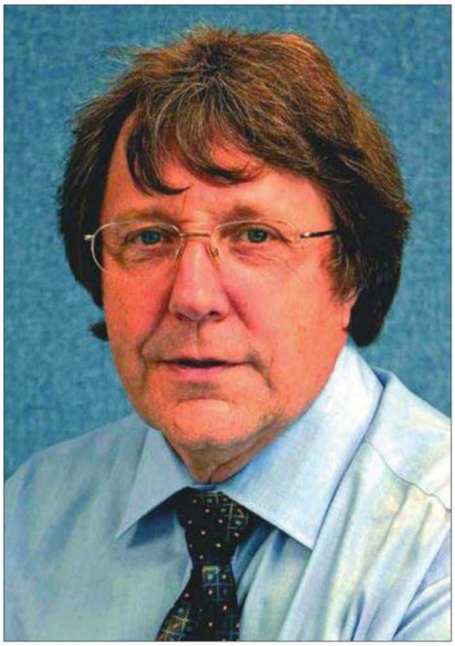
large orbital waverider as its second stage and a nuclear-powered third stage, and this was to be capable of transporting British astronauts to the Moon's surface!

Many of the Hawker Siddeley manned spacecraft studies were unrealistic from the outset, although a few further proposals for mini-shuttles based on two-and-a-half-stage launch systems produced during the 1960s have the appearance of viable designs. (There is some confusion about the definition of a '½-stage', but it appears to be generally accepted that half-stages are jettisonable fuel tanks or sometimes boosters). Needless to say there was little enthusiasm in Whitehall for any of HSA's ambitious space projects, no commercial backers and the plans were soon forgotten.

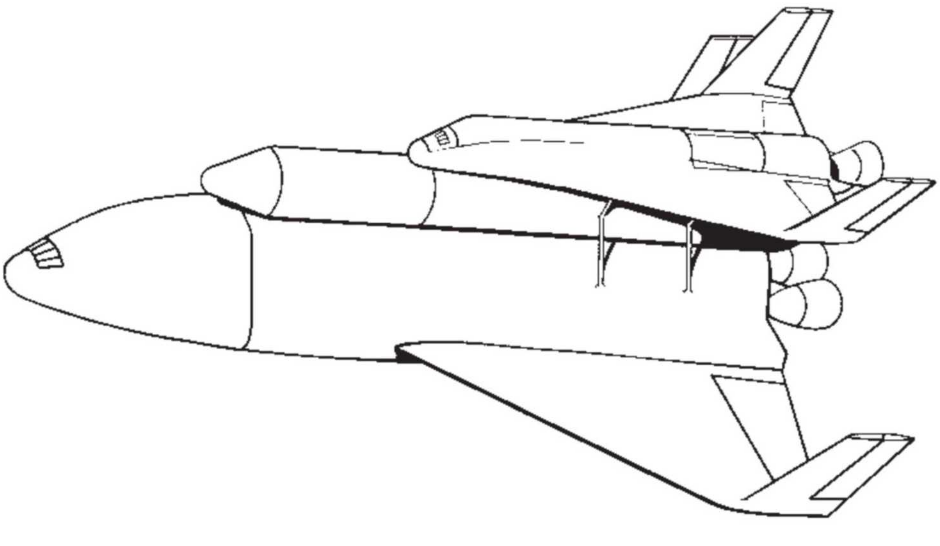
HOTOL

In 1982 a scientist working for the UK Atomic Energy Authority called Alan Bond began to investigate the idea of building an efficient rocket engine system that was suitable for use with an SSTO spaceplane. Bond had worked for Rolls-Royce's Rocket Division where he accumulated a great deal of experience with rocket engine design having been involved with the Blue Streak missile programme. However, he was better known outside the industry as a member of the 1973-1977 BIS Design Group who produced a detailed engineering study for a hypothetical fusion-powered starship called Daedalus. There were several options available to Bond for an SSTO propulsion unit. The first and simplest choice was to use a combination of turbo-ramjets and separate liquid fuel rocket engines. He soon decided against this because it meant having to carry unnecessary excess weight into space. Another possibility would be some form of supersonic combustion ramjet (scramjet) which could draw on air from the atmosphere. The scramjet was theoretically capable of achieving very high Mach numbers but needed to reach a substantial speed before it could operate, so it was not possible to use this design as a stand-alone unit.

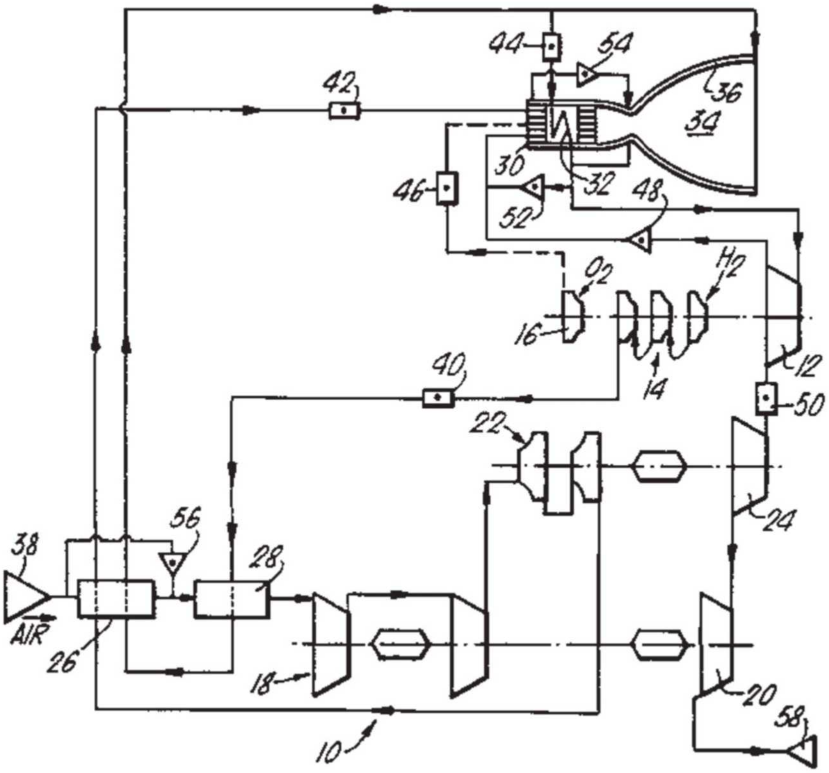
Then Bond turned his attention to the Liquid Air-Cycle Engine or LACE, which was not an entirely new concept. Marquardt and General Dynamics tested small experimental rigs in the early 1960s but there were numerous design problems and nobody managed to make one work properly. The idea behind the LACE was to gather oxidiser during the ascent using a suitably configured intake. Although technically challenging, the oxygen would then be separated and stored in liquefied form for use above the atmosphere. The difficulty was finding the ability to collect sufficient oxygen while climbing through the lower atmosphere and the sheer mechanical



Bottom left: **Rocket propulsion expert Alan Bond who designed the HOTOL SSTO spacecraft propulsion system.** Reaction Engines Ltd



Bottom right: **A 1960s Hawker Siddeley design by Hugh Francis for a 2½-stage Mini Shuttle orbiter system.** British Aerospace



The original 1983 schematic for Alan Bond's rocket engine design, which was assigned the Rolls-Royce reference RB545. US Patents Office

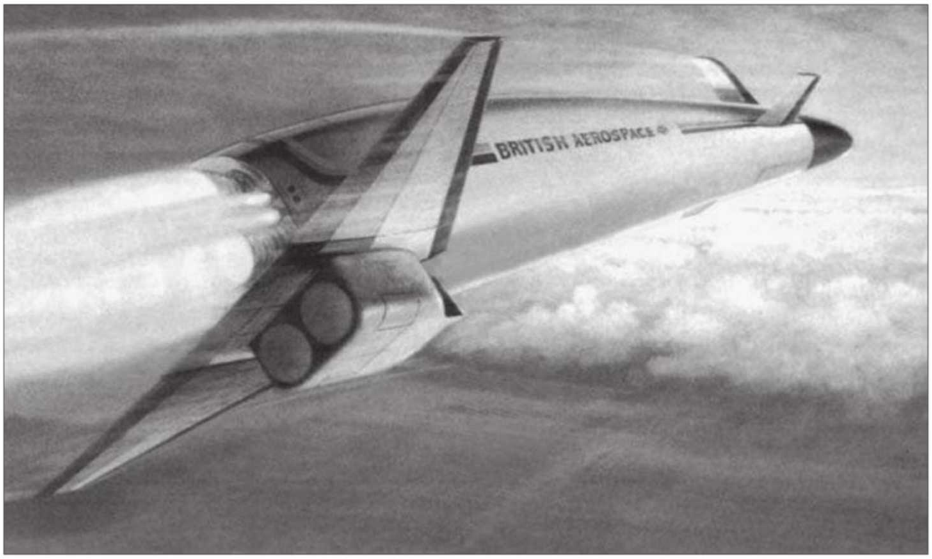
complexity of the engine. These problems might have seemed insurmountable, but Bond set about finding solutions using little more than his own personal Sinclair Spectrum computer, which would now be regarded as very basic when compared to the lowest spec. modern PC. By 1983 he had come up with a series of answers and produced a new design which used a heat exchanger pre-cooler located after the air inlet ramp (that also led to the spill duct and ramjet burner). The heat exchanger was then (physically) followed in the craft's body by a complex air compressor and drive turbine to provide oxygen extracted from the atmosphere while it was available. Although the design was fairly complex, it would allow a substantial weight saving and make a fully re-usable SSTO spaceplane feasible.

Rolls-Royce soon became involved with the project, assigning the company reference RB545 to Bond's design which in 1983 he filed for a UK Patent. Meanwhile, Robert Parkinson who worked as an aerodynamicist for British Aerospace (BAe) had started to develop some new ideas for a reusable launch vehicle capable of putting 7 tons (6.4 tonnes) into LEO. As a consequence of this, Parkinson and Bond were soon collaborating on the design of a revolutionary new space launcher called HOTOL (Horizontal Take-Off and Landing).

Numerous evolutionary changes took place. The initially proposed canard foreplanes were deleted, the active forward fin modified, the two tail fins were removed completely and the conical intakes were changed to 2-dimensional vertical wedge shapes. The definitive version of HOTOL would have a length of 246ft (75.0m), a core diameter of 22ft 11½in (7.0m) and a wingspan of 92ft (28m). Total mass was estimated at 550,000 lb (250,000kg) or 245 tons (222 tonnes) and it would weigh 110,231 lb (50,000kg) empty. Three RB545 engines would provide a lift-off thrust of 708,600 lb (3,152kN), but the arrangement was later changed to four engines.

HOTOL would be capable of operating from conventional runways like an aircraft, although it would utilise a rocket-powered wheeled sled to take-off. A modest tricycle undercarriage would be used for landings but this would only be strong enough to support the spaceplane when it was empty. Anything more substantial would have a serious impact on payload capability. (It is not uncommon to find spacecraft with very lightweight undercarriages only able to support the vehicle in an empty condition. This saves a huge amount of weight and is only going to matter in a launch abort/emergency situation. The extra weight takes up payload capability and this is critical.) After separation the sled would descend by parachute and the HOTOL vehicle would be powered entirely by its RB545 engines. At an altitude in the region of 85,000 to 105,000ft (26,000 to 32,000m) and a speed of about Mach 6, the RB545 engines would switch from air breathing to rocket propulsion and a supply of liquid oxygen would be used to maintain engine power until Mach 25 was achieved. HOTOL would be unmanned and flown by remote control, and increasing autonomy would be introduced as computer technology evolved.

The cost of delivering 7 tons (6.4 tonnes) of cargo into LEO was initially estimated at £5 million, although this may have been a little optimistic, and it was anticipated that HOTOL

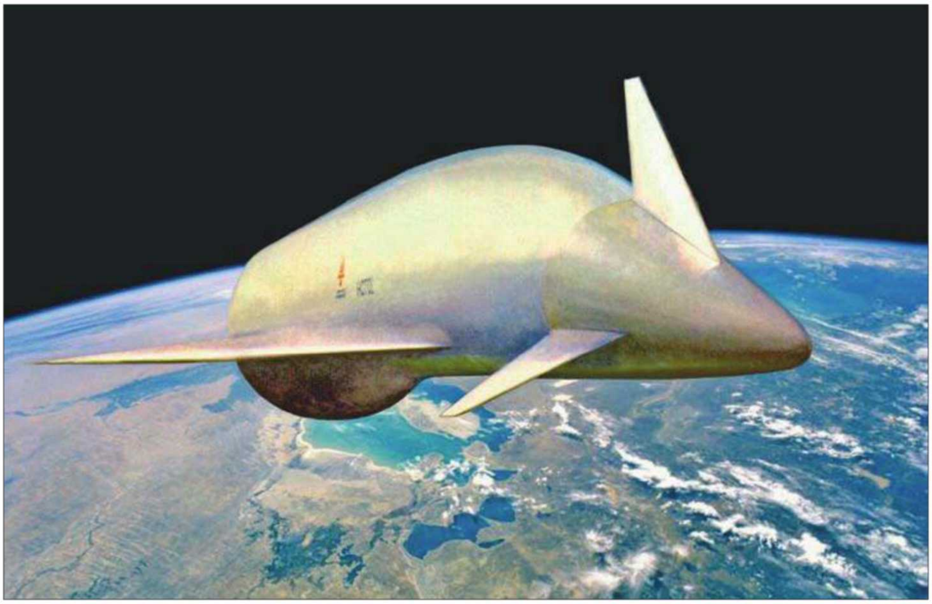


The HOTOL spacecraft climbs rapidly towards orbit. British Aerospace

Right: **HOTOL in orbit.** British Aerospace

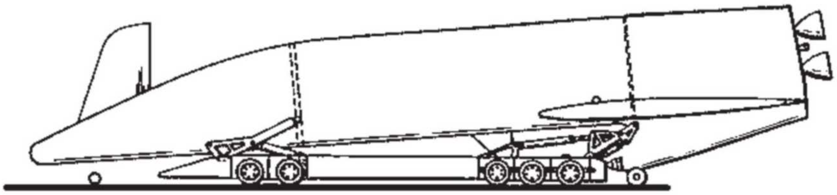
Below right: **Designed to operate from a conventional runway, HOTOL would utilise a multi-wheeled rocket powered sled for take-off. The spaceplane would be equipped with a tricycle undercarriage, but for weight saving reasons this would only be sufficient to support the vehicle with empty fuel tanks.** British Aerospace

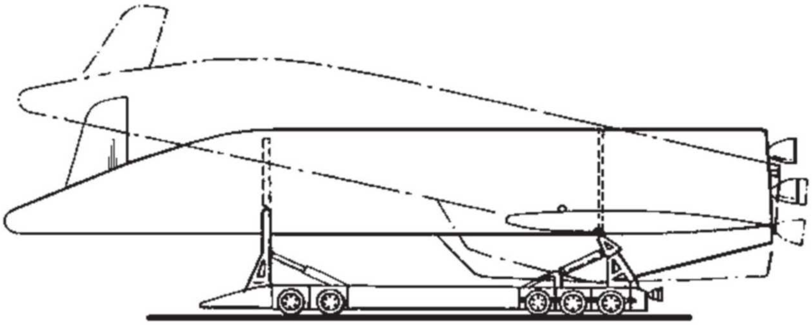
Below left: **John Scott-Scott was heavily involved in the development of the RB545 engine.** Reaction Engines Ltd

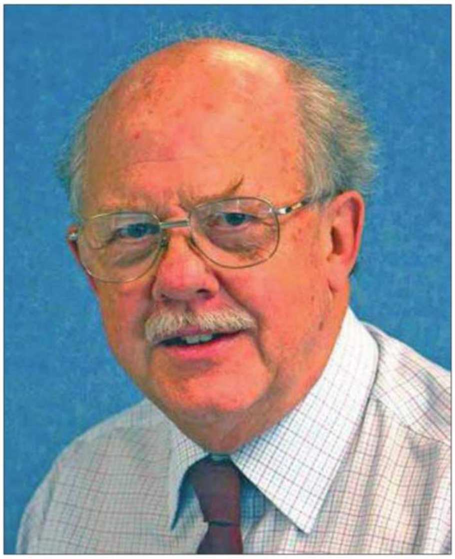


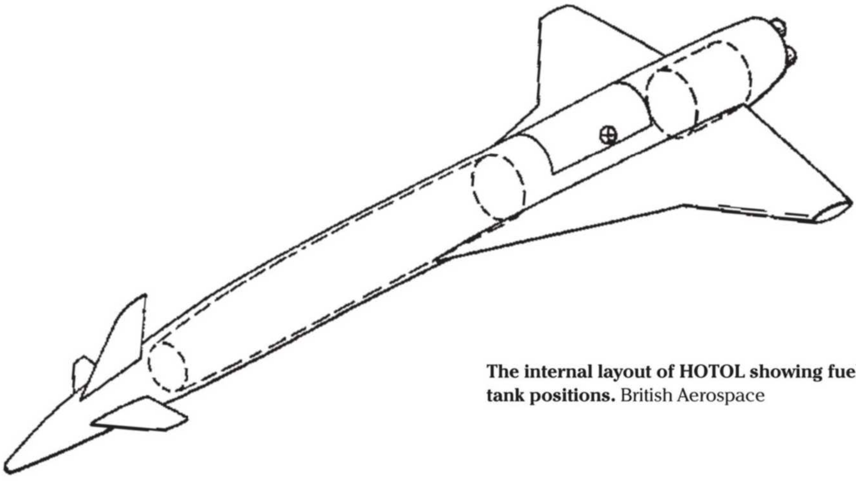
could easily be adapted to manned missions. On completion of each mission HOTOL would de-orbit, make a controlled re-entry and glide to the landing site. In July 1984 the *News At Ten* television programme revealed HOTOL to the general public and in September a model was displayed at the Farnborough Air Show, although the engine technology was not described in any detail. Not surprisingly the disclosure of HOTOL generated many media stories which described global flights from cities like London to Sydney, Australia in forty-five minutes, and gave the impression that this capability would be commonplace by the year 2000.

But there were problems after a patent application was filed for Bond's engine. It was referred to a Ministry of Defence (MoD) review panel which decided to classify the design as top secret. As a consequence details of the RB545 would remain unavailable for the next eight years and commercial opportunities became seriously restricted. This was something of a setback, but in 1986 BAe was awarded £2 million by the Government to continue with HOTOL studies at Stevenage, Warton and Filton. About one hundred members of staff were now involved in some aspect of HOTOL research and John

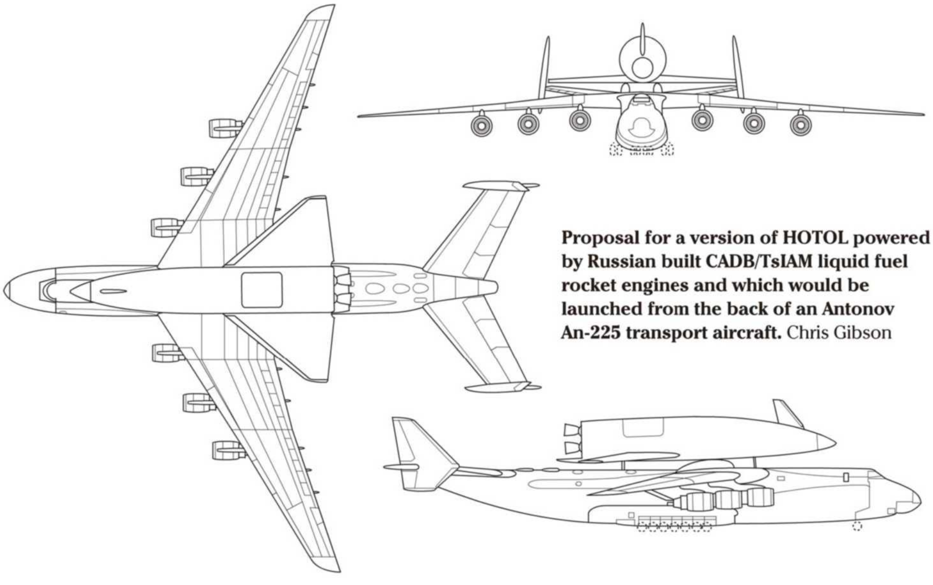








The internal layout of HOTOL showing fuel tank positions. British Aerospace



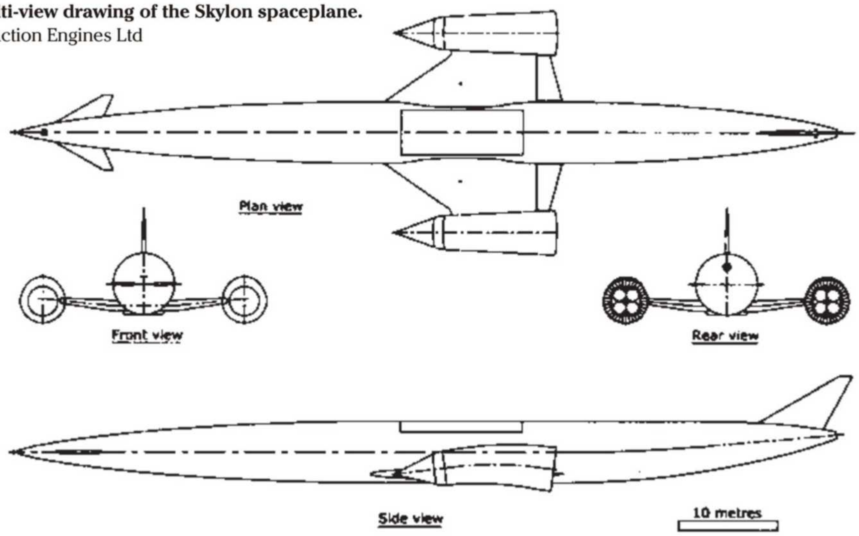
Proposal for a version of HOTOL powered by Russian built CADB/TsIAM liquid fuel rocket engines and which would be launched from the back of an Antonov An-225 transport aircraft. Chris Gibson

Scott-Scott was placed in-charge of further RB545 development. Bond continued to work on engine integration, which included the wind tunnel testing of models, but in 1988 he decided to sell the rights for the engine design to Rolls-Royce. The following year the project was unexpected scrapped when the Government refused to fund any further development. Although a brilliant concept, it now looked as if Government ministers regarded HOTOL as little more than a prestigious high-profile study that could be used for political advantage. Had the Thatcher Government been committed to fully developing HOTOL, it would have required an investment of several billion pounds and this kind of money was simply not available.

Interim HOTOL

Unfortunately for British Aerospace and Rolls-Royce, the Government refused to declassify details of the engine technology developed by Alan Bond. This made it impossible for BAe and Rolls to enter into any development arrangements with foreign partners. With the project at a standstill Rolls-Royce decided to abandon research into hypersonic propulsion, which caused the Government to back-pedal a little saying it would reconsider the situation if an international partner was found. But it was now too late to prevent Alan Bond, John Scott-Scott, Richard Varvill and some of the other HOTOL scientists from leaving BAe and setting up their own independent company.

Multi-view drawing of the Skylon spaceplane.
Reaction Engines Ltd

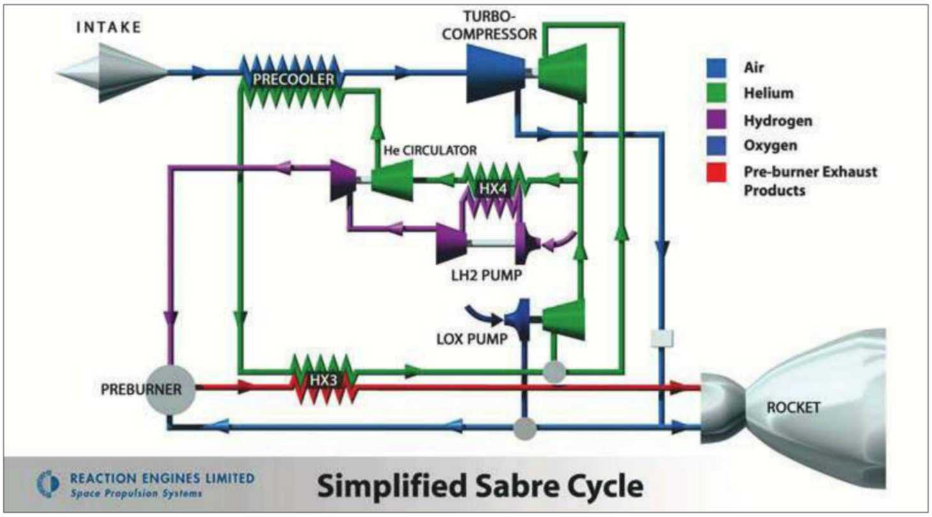


In August 1989 they established Reaction Engines Limited, with the aim of continuing to develop advanced spaceplane and rocket engine technology. The same year Robert Parkinson and his colleagues at BAe entered into talks with the Russians about the idea of jointly developing a slightly smaller version of the HOTOL spaceplane that would be powered by conventional Russian CADB/TsIAM liquid fuel rocket engines and launched from the back of the very large Antonov An-225 transport aircraft (NATO codename *Cossack*). This led to an agreement, finalised in 1990, to undertake an Anglo-Russian study that would last nine months and be presented to the European Space Agency (ESA). The study was completed in June 1991 and indeed submitted to the ESA, but it failed to secure development funding. This revised HOTOL, now called Interim HOTOL, would be capable of placing a 4.5 ton (4.1 tonne) payload into LEO. It would utilise four Russian-built rocket engines, providing some degree of redundancy for launch emergencies, with separation from the An-225 taking place at an altitude of about 30,000ft (9,150m).

However, this was a politically turbulent time for Russia and, during the Interim HOTOL study, NPO Molniya (a major Russian rocket launch development organisation responsible for the Buran shuttle) revealed that it had already been working on a very promising spaceplane called MAKS. This was also designed for launch by an An-225 and expected to deliver almost twice Interim HOTOL's payload to LEO. Much of the initial MAKS hardware had been fabricated and was in storage and this mini-shuttle appears to have been a very good design that was earmarked to eventually replace the Russian Soyuz spacecraft. Although the Russians were sliding towards economic meltdown, the discussions about Interim HOTOL soldiered on until 1992. But the existence of MAKS was unhelpful and there were no potential customers for either system, so Interim HOTOL was finally abandoned.

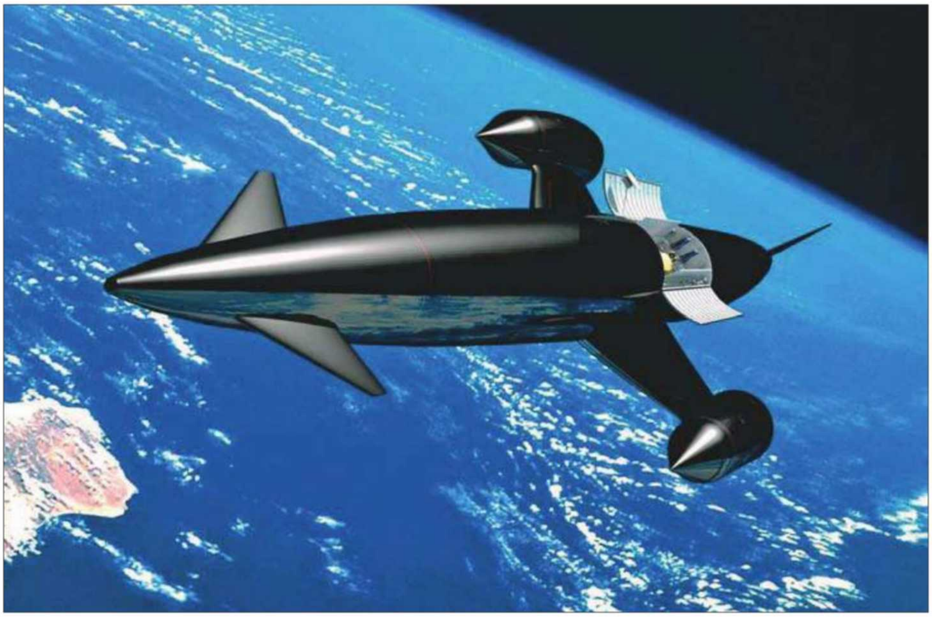
Skylon

In 1990 Alan Bond started work on the design of a new spaceplane. There were technical problems with HOTOL that would have been difficult and expensive to overcome, so the new concept started out by addressing these issues and improving on the overall design. The new spaceplane was called Skylon and would have the same take-off mass as HOTOL, but it would be capable of lifting 12 tons (11 tonnes) into LEO. Although the



An illustration outlining the basic operation of the Sabre air-breathing rocket engine. Reaction Engines Ltd

HOTOL's successor – the more advanced Skylon SSTO spaceplane. Reaction Engines Ltd

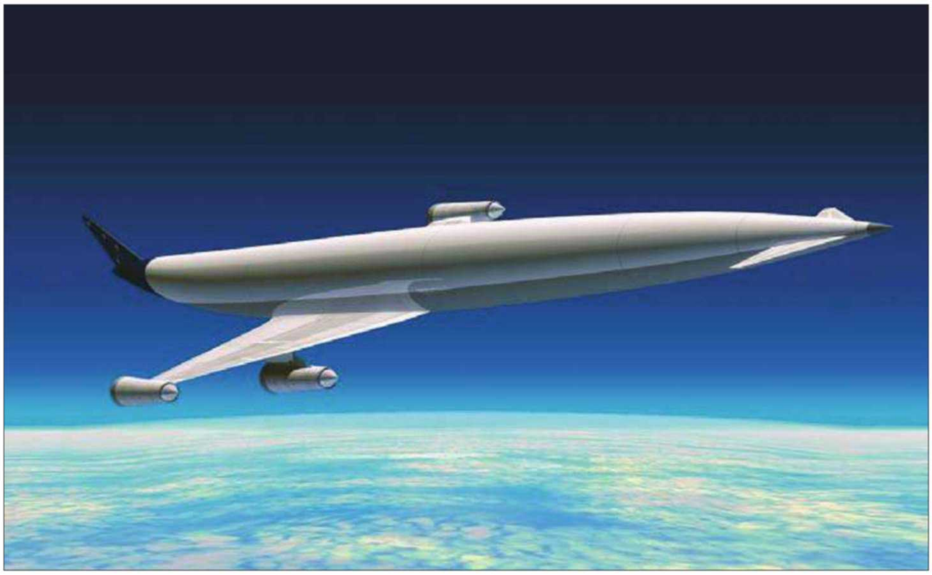


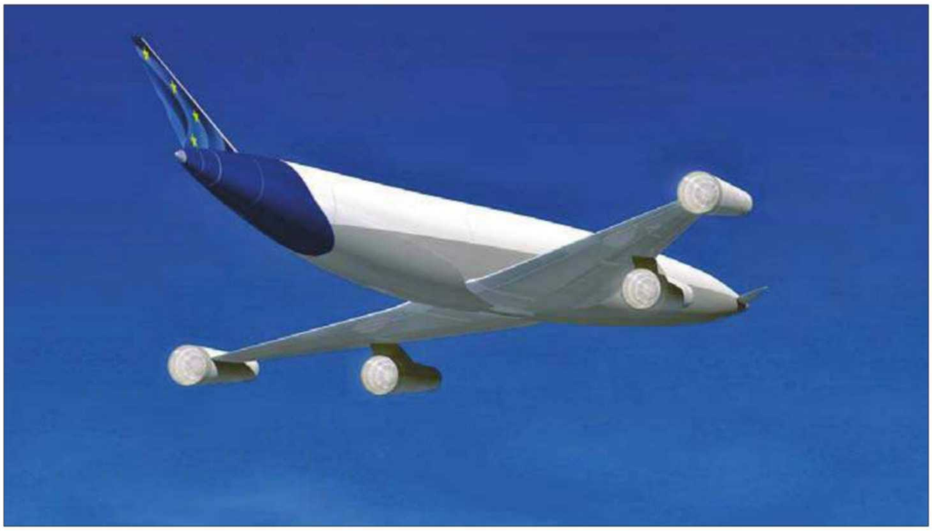
The Skylon spacecraft was to be powered by two SABRE engines which operate on similar principles to the RB545. Reaction Engines Ltd

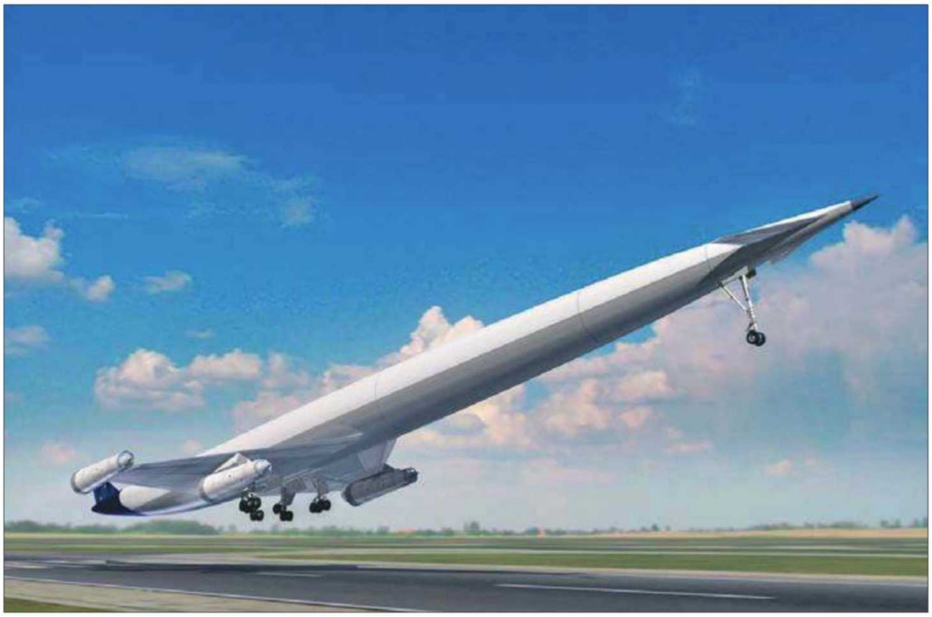
patents for the RB545 engine were now owned by Rolls-Royce, Bond updated the design and improved the thermodynamic cycle, leading to significantly better performance. The new liquid-fuelled engine, called SABRE for Synergic Air Breathing Engine, worked on similar principles to the RB545, but the appearance of the Skylon spaceplane differed considerably from HOTOL with the propulsion now coming from two engines in wingtip nacelles.

The proposed length for Skylon was 269ft (82m), it had a core diameter of 20ft 6in (6.25m) and a wingspan including the engine nacelles of 82ft (25m). Gross take-off weight would be 275 tons (250 tonnes) and landing weight was expected to be 55 tons (50 tonnes). Thrust from the two SABRE engines during air-breathing ascent would be approximately 200 tons (1,780kN), rising to 300 tons (2,670kN) at hypersonic speeds. This would be throttled down towards the end of the burn to limit the longitudinal acceleration to 3G. The flight profile would be somewhat similar to HOTOL, although Skylon would make a runway take-off using its more substantial retractable undercarriage. The spaceplane would climb steeply to about 85,000ft (26,000m), reaching a speed of approximately Mach 5, and then the SABRE engines would switch to pure rocket propulsion for the remainder of the journey into orbit. The changeover point to rocket propulsion at this height and speed was now considered optimal. Skylon would be capable of delivering a 12 ton (10.9 tonnes) payload to a 186-mile (300km) equatorial orbit or a 10.5 ton (9.5 tonnes) payload to a 285-mile (460km) orbit. From an equatorial launch site it could deliver 9.5 tons (8.6 tonnes) of load to a 285-mile (460km) orbit with a 28.5° inclination.

For the return to Earth, re-entry into the atmosphere would begin at an altitude of between 200,000 to 300,000ft (61,000 to 91,000m) and the aeroshell would be made from a fibre-reinforced ceramic. Advanced composite materials would be used for the fuselage and load bearing areas, while the fuel tanks would be internally suspended and able to adjust to changes in heat and







pressure. During the ascent it would be possible to control the vehicle with engine gimballing, while in orbit a reaction control system would be used for manoeuvring. While returning to base, ailerons would control roll, a tail fin would control yaw and canards would control pitch. It was anticipated that one Skylon spaceplane would be capable of being re-used two hundred times and vehicle turnaround time would be roughly two days between flights. Skylon was designed from the outset as a freighter, although it could be fitted with a module currently designed to carry thirty-six passengers. The payload bay would be 40ft 4in (12.3m) long with a diameter of 15ft (4.6m) and ground handling operations could be undertaken with standard equipment. Loading cryogenic propellants would be automatically handled via connectors in the undercarriage that were operated while Skylon was on the fuelling apron.

With a size comparable to a Boeing 747, the design philosophy behind this spaceplane has been simplicity, ease of use and reliability. Skylon represents a significant improvement over HOTOL in almost every respect and the initial studies were completed in 1995. However, Reaction Engines have been unable to find the kind of financial backing needed to fully develop the concept.

Lapcat

A spin-off design from the Skylon project is a hypersonic transport aircraft called Lapcat. Having intercontinental range, Lapcat would cruise at a speed of Mach 5 at 100,000ft (30,480m) and use propulsive technology based on the SABRE engine. This new air-breathing pre-cooled engine is called Scimitar, it is fuelled by liquid hydrogen and, in addition to providing hypersonic cruise, has a lower speed mode with high bypass airflow that reduces take-off noise to that of a conventional turbofan. Promoted as the next step forward from Concorde, it would still cost a great deal of money to develop. The commercial scope for this kind of aircraft appears somewhat limited at present, although Reaction Engines remain surprisingly optimistic about future developments.

Concept artwork showing the hypersonic Lapcat transporter cruising at approximately 80,000ft (24.3km). Reaction Engines Ltd

Developed from the Skylon spaceplane, Lapcat would cruise at Mach 5 and possess intercontinental range. Reaction Engines Ltd

An artist's illustration of Lapcat leaving the runway. Reaction Engines Ltd

Chapter Three

US Projects

In the immediate aftermath of World War Two the Allies deployed large teams of scientific intelligence officers to secure advanced German military technology and locate the scientists and engineers who had made this possible. In the case of the Peenemünde rocket scientists, a sizeable contingent of staff led by Wernher von Braun and General Walter Dornberger made their way towards American lines, fearful of being captured by the approaching Soviet forces. This was an especially difficult journey for von Braun who had broken his arm in a car accident some weeks earlier. The scientists were now hiding out in a number of Bavarian villages and on 2nd May 1945 Dornberger, von Braun and several others made themselves known to members of the US 44th Infantry Division at Reutte. Once the American officers had identified them as rocket scientists, the entire group was taken to a hotel at the ski-resort Garmisch-Partenkirchen. Many of the engineers were allowed to return to their homes, but the senior members of the group remained in custody.

The Americans and British now began to interrogate the scientists. Although a good deal of rocketry hardware had been secured most of the documentation from Peenemünde was missing. In fact, no less than 14 tons (12.7 tonnes) of documents had been hidden in an abandoned mine near a small village called Dornten by one of von Braun's associates called Dieter Huzel. Realising the war was lost, von Braun had arranged this to prevent the documents from being destroyed by the SS on General Kammler's orders and he hoped to use this material as a means of bargaining with the Americans. But von Braun had underestimated US Intelligence who got wind of the general location where the documents were hidden and managed to track them down. This material was then shipped to the Aberdeen Proving Ground in Maryland. Britain was already undertaking a programme known as Operation *Backfire* which aimed to secure rocket technology and know-how, so there was initially a good deal of cooperation with the Americans. However, national interests soon began to interfere with joint operations and, unfortunately, the arrangement became rather one-sided when the Americans were holding Germany's top rocket specialists and shipping every piece of hardware that looked useful back to the US.

While the jointly handled interrogations of von Braun's staff continued, the Soviets began to take a keen interest in proceedings and the KGB managed to approach Dornberger while he was in American custody. They promised to double whatever the Americans were offering to work for them but Dornberger rejected this proposal. Some weeks later KGB officers dressed in British uniforms tried to kidnap von Braun and Dornberger while they were billeted in Witzenhausen. The attempt might have succeeded if several alert security staff had not become suspicious.

In June 1945 the British suggested that the Germans should be allowed to test launch several A4 rockets so that procedures could be carefully observed and recorded. General Eisenhower agreed to these trials and this led to the launching of three inert rockets under British supervision during October at Cuxhaven. The Americans had already begun

On a wet and miserable day in May 1945 Wernher von Braun (who had broken his arm in a traffic accident), General Walter Dornberger and a large number of former Peenemünde rocket scientists surrender to American officers from the 44th Infantry Division at Reutte. Bill Rose what was initially called Operation *Overcast* but was later re-named Operation *Paperclip*. The change of name came about because those selected for transfer to the United States had paperclips attached to their records. Although some of these German scientists and engineers might have warranted trial as war criminals, such considerations were swept under the carpet and they were offered five-year contracts to work in the United States.

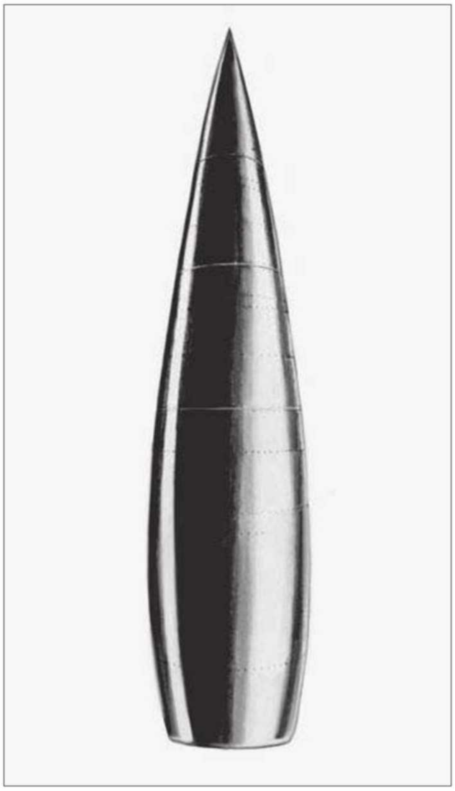
The British had been given responsibility for the German scientists and began returning them to the Americans, but they insisted on holding on to von Braun, Dornberger and a few other senior scientists for further interrogation of a technical nature. This was actually untrue and they were really being held for political reasons. Eventually the British flew these senior Peenemünde staff to London and took them on a tour of sites hit by A4 (V-2) rockets so they could see the effects of their work. However, the Americans were losing patience with the British and insisted that the Germans were returned to US custody. The British complied but retained Dornberger, having decided that he should stand trial as a war criminal. Dornberger was then interned at Island Farm Camp in Wales until 1947 and, from all accounts, he did not get on very well with his British captors. Eventually, American pressure secured his release and Dornberger was taken to America under Operation *Paperclip*.

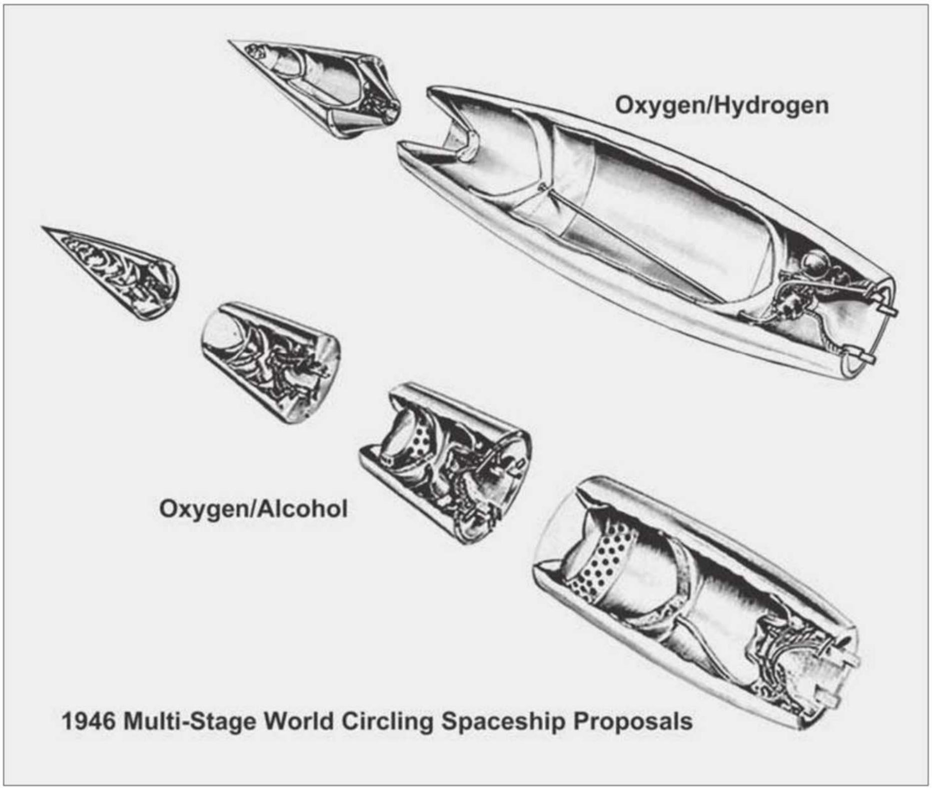
A V-2 is prepared for a test launch by a German crew under the British-organised Operation *Backfire* programme. Bill Rose

German scientists had been arriving at Fort Strong, New York since September 1945 and many of them were then sent to the US Army Aberdeen Proving Grounds in Maryland to assist with the efforts to sort and categorise the Peenemünde documents. Later in the year German rocket engineers arriving in America went directly to Fort Bliss in Texas. This was relatively close to the newly established White Sands Missile Range (WSMR) in New Mexico where large quantities of captured rockets and components had been shipped.

Duplication and development of the rocket technology was given top priority by the Pentagon, with the first static engine test taking place at WSMR on 14th March 1946 and the first test launch of a captured A4 on 16th April. The development programme was intensive and by 1947 A4s were being modified and stretched by about 5ft (1.5m) to accept larger fuel tanks. Throughout this period von Braun continued to develop and refine his own ideas and designs, which were enthusiastically greeted by the Americans. He produced drawings and plans for long-range rockets, spaceships and space stations which had a major impact on the thinking of senior Pentagon officials. They were already concerned about what kind of advanced technology the Russians might develop during the coming years and it seems that von Braun was a very good salesman for his own cause.

One particular suggestion put forward by von Braun was for a 'World-Circling Spaceship' and the Pentagon immediately issued a study contract to North American Aviation and Martin, although the idea of achieving orbit with a single stage vehicle was somewhat unrealistic. USAAF General Curtis LeMay then decided to place a request with Project RAND (who were a branch of Douglas Aircraft at that time) to conduct a related study into a space satellite system. This resulted in report No SM-11827, issued on 2nd May 1946, called 'Preliminary Design of an Experimental World-Circling Spaceship'. The RAND team highlighted the military potential of an Earth satellite system, primarily for photographic reconnaissance missions, and it examined the possibility of recovering the vehicle from orbit. Unlike the other studies the team had chosen a launch system based on the later German multi-stage rocket proposals, but concluded that the techno-




Oxygen/Hydrogen
Oxygen/Alcohol
1946 Multi-Stage World Circling Spaceship Proposals

Above left: **Von Braun's design for a World-Circling Spaceship, intended to place a small satellite in orbit.** Bill Rose but based on a US Army drawing

Above right: **RAND proposal for a World-Circling Spaceship developed from von Braun's 1945 design. The four-stage rocket would have utilised engines fuelled with alcohol and LOX and a more advanced two-stage concept would use engines fuelled with liquid hydrogen.** Douglas Aviation

logical requirements were too demanding.

The World-Circling Spaceship may have been a step too far, but von Braun continued to develop his ideas for space exploration. These eventually surfaced during 1952 in *Collier's Weekly* magazine as a series of articles entitled 'Man Will Conquer Space Soon!' He proposed the construction of a huge multi-stage Ferry Rocket weighing several thousand tons that was 265ft (80.7m) long and had a base diameter of 65ft (20m). This would lift a fully re-usable winged upper stage into orbit. With his sights set on manned flights to the Moon, Mars and Venus, von Braun saw the winged spaceplane as a basic building block for all future big budget American missions. In 1953 von Braun produced a book called *The Mars Project* and Hollywood director George Pal used it as a basis for the 1955 movie *Conquest of Space*, which was set in the mid-1980s. These ideas had a major impact on Pentagon thinking and von Braun's enthusiasm for rocket development and space exploration ensured that his team were well looked after by the Army.

The senior German scientists quickly adapted to life at Fort Bliss, which was a substantial military facility near El Paso. They were a long way from home but life in Europe remained tough and the new environment had much in its favour. Furthermore, this was a golden opportunity to continue their work with very substantial development budgets available. The Germans began to liaise directly with engineers and scientists from the major US defence contractors and they would make regular trips to WSMR to assist with rocket assembly and test launches. The pace of development never slackened and von Braun would soon have his wish to see a rocket derived from his original design launch a small payload into space.

WAC Corporal

The WAC Corporal followed on from a small 8ft (2.43m) long solid propellant experimental rocket called the Private A which had been developed by the Jet Propulsion Laboratory (hence the name 'Corporal'). WAC is thought to mean 'Without Attitude Control'. This test rocket entered development in 1944 and was related to the much larger nuclear-tipped Corporal ballistic missile which entered service with the US and British armies during the 1950s. Corporal was followed by a nuclear-tipped battlefield missile called Sergeant, which represented a significant improvement. WAC Corporal would also assist in the development of the Viking and Vanguard rockets. WAC Corporal was designed for the US Army Signal Corps who initially required a small rocket capable of carrying a 25 lb (11.3kg) payload to 100,000ft. The rocket was 24ft 1in (7.34m) long (including its booster), it had a diameter of 12in (304mm) and used a solid-propellant 'Tiny Tim' first stage with a lift-off thrust of 50,000 lb (222.4kN). The liquid-fuel second stage produced a thrust of 1,500 lb (6.67kN). Tests of the rocket began at WSMR in September 1945 and one WAC Corporal reached a maximum altitude of 43.5 miles (70km).

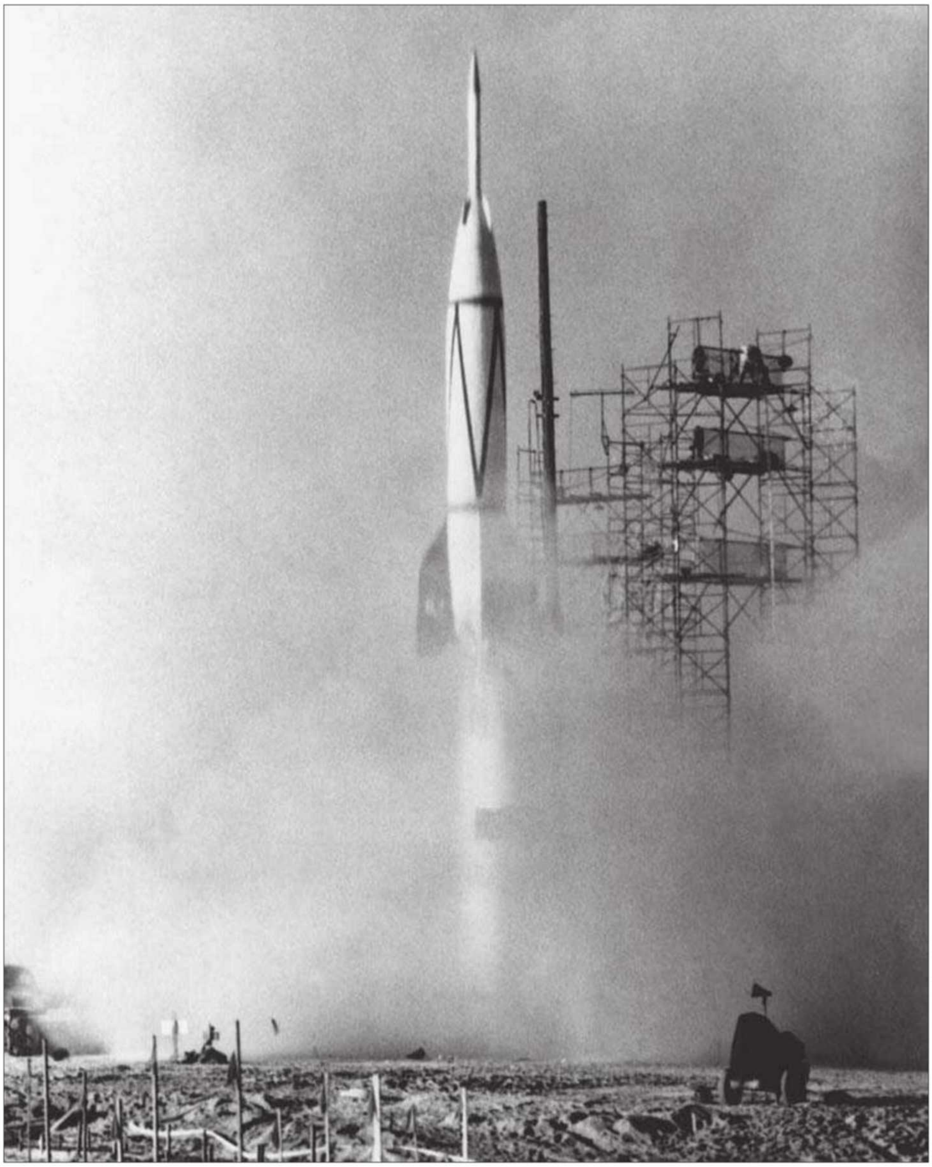
This led to the suggestion that a WAC Corporal rocket might be mated with a German A4 to provide an upper stage and the new rocket became the Bumper-Wac. Eight A4 rockets were adapted to this two-stage configuration and the first six were launched from WSMR (the fifth was launched on 24th February 1949), reaching an altitude of 244 miles (392.6km) to become the first man-made object to reach space. This was the most ambitious development of the A4 (V-2) rocket undertaken by the Americans under Project Hermes and development of bigger rockets derived from A10/11 proposals remained on hold for some time. The remaining two Bumper-Wac rockets were launched from Cape Canaveral in mid 1950.

Hermes

With a finite number of captured A4s at its disposal the US Army contracted General Electric to produce more rockets to supplement existing stocks under an existing programme called Project Hermes (not to be confused with the later ESA Hermes spaceplane). Project Hermes had been initiated in 1944 by the US Army as a plan to duplicate German rocket technology and this also resulted in the decision made in 1946 to build a sub-scale A4 rocket called Hermes A1, which was based on the German Wasserfall (Waterfall) surface-to-air missile, itself a development of the A4.

The Soviets took a similar path building their own version of the Wasserfall called the R-101. In many respects Wasserfall was a more advanced missile than the A4 and it used a different liquid propulsion system employing visol (vinyl isobutyl ether) and salberi (a nitric/sulphuric acid combination). This hypergolic mixture could be stored in the fuel tanks for up to one month and allowed the missile to stand ready for immediate launch.

Wasserfall weighed 8,157 lb (3,700kg) at launch and carried a large 517 lb (235kg) warhead. The warhead's specification was altered a number of times during development. Overall length was 7.85m, core diameter 34.5in (880mm) and range from a fixed site was 15.5 miles (25km). The first prototype Wasserfall had been tested at Peenemünde in 1943, but when Dr Walter Thiel who designed this missile's propulsive system was killed during an RAF bombing raid, its development was held up for another year. A number of test launches were made but, despite several claims, this missile was never fired in anger. Had the war lasted longer Wasserfall was scheduled to enter service in November 1945.



Wasserfall used a radio guidance system and a similar form was adopted for Hermes, although work was under way to upgrade this to a more advanced beam riding system. The General Electric Hermes A-1 was broadly similar to Wasserfall but was built as an 'affordable' research rocket fuelled by oxygen and alcohol. Launches began in 1950 and the Hermes rocket led to a range of experimental derivatives and to plans for a short-range solid fuelled nuclear battlefield missile known as the SSM-G-13. This design never progressed very far, but the Hermes research programme would be used to develop the US Army's SSM-A-27/MGM-29 Sergeant and SSM-A-14/PGM-11 Redstone missiles.

The most mysterious part of the Hermes programme was the B Series, which tested ramjet upper stages launched with an A4 rocket. The ambitious goal was to develop a ramjet powered surface-to-surface missile capable of carrying a 1,000 lb (453kg) warhead over a distance of 1,000 miles (1,600km) at a speed of Mach 4. The Hermes upper test stage was called 'Ram', it was partly recessed into the rocket and was fitted with small foreplanes and large slab-shaped wings (called the 'Organ') which acted as inlets to the ramjet engine. However, the first launch of a nonfunctional dummy Ram upper-stage in 1947 went disastrously wrong. The rocket veered off course and crossed the border into Mexico before crashing into a graveyard and causing major political embarrassment.

Further flights carrying functional Ram test vehicles followed, although there is some

Left: **The launch of Bumper 1 at Cape Canaveral in 1950. The upper stage of this high-altitude V-2 rocket used a WAC Corporal sounding rocket.** NASA

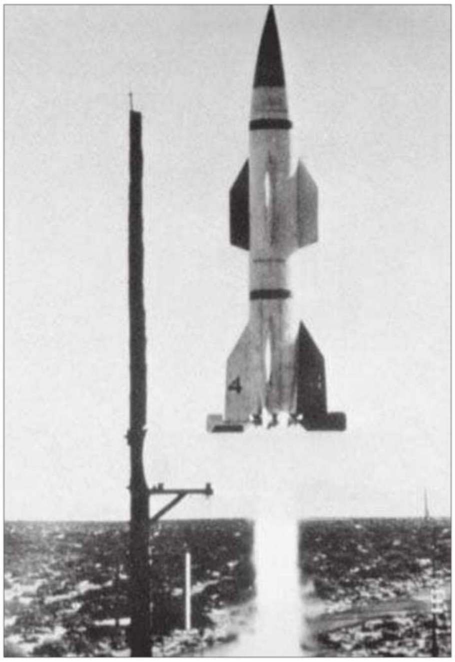
Opposite page:

Top left: **American research version of the wartime German Wasserfall (Waterfall) surface-to-air missile known as Hermes A-1.** Bill Rose

Top right: **Native test rockets built in America undertook a small number of flights during 1948, although the failure rate appears to have been quite high and the programme was abandoned in early 1949.** US Army

Bottom left: **The RTV-A-3 North American Test Instrument Vehicle (NATIV) was based on German Wasserfall and A5 rockets.** US Army

Bottom right: **Developed under the US Hermes programme, this highly classified Mach 3.3 ramjet experiment was designated Hermes II and launched using a V-2 rocket.** US Army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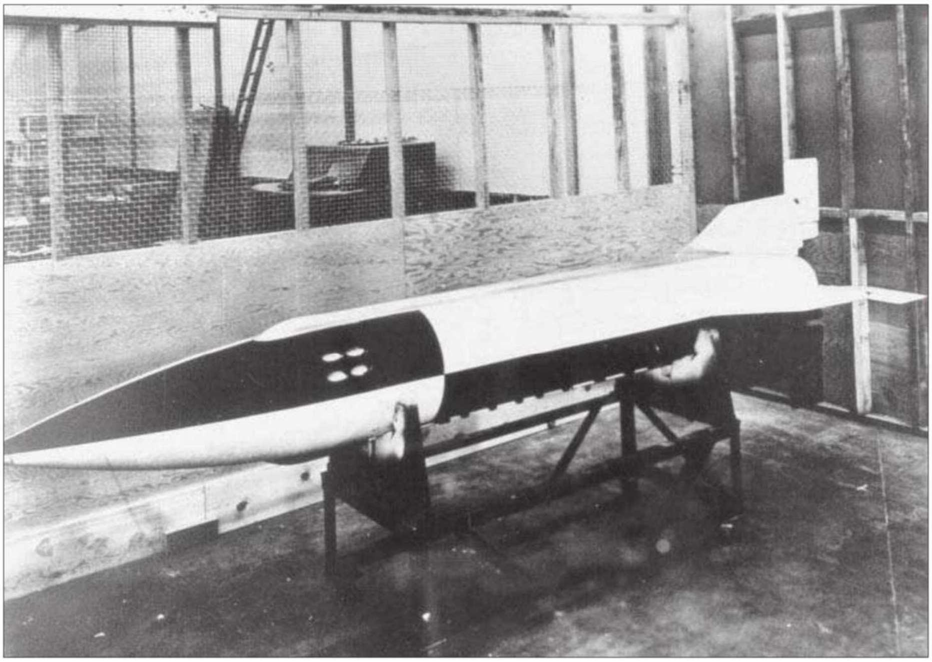
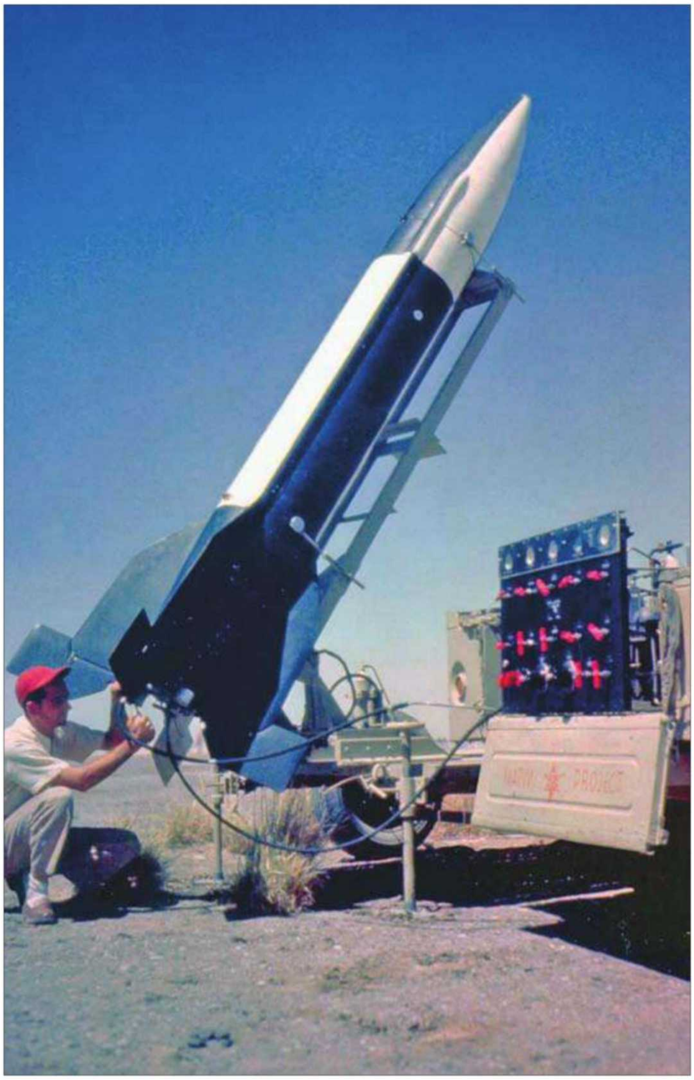
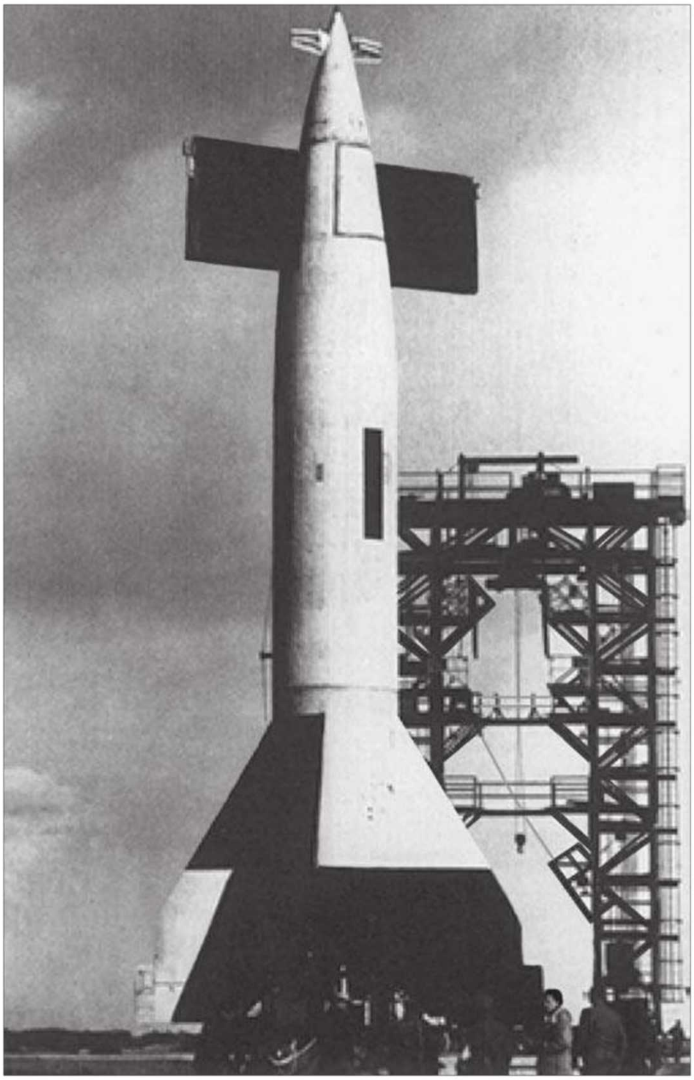



NAVY PROJECT



dispute about what exactly took place because this work was classified top-secret and accessible documentation is rather unclear. There were proposals by General Electric to develop a larger rocket with a ramjet upper stage known as Hermes C. This was expected to have a 2,000 mile (3,218km) range and might have formed the basis for an operational weapon. But this missile was never built and there is some confusion about this designation, which was used in some documentation to describe plans for the Redstone missile. Between 1946 and 1952 more than sixty rockets based on the A4 were launched and many of these contained scientific payloads, although the underlying objective was to gain experience that could be used in the development of military weapon systems.

Redstone

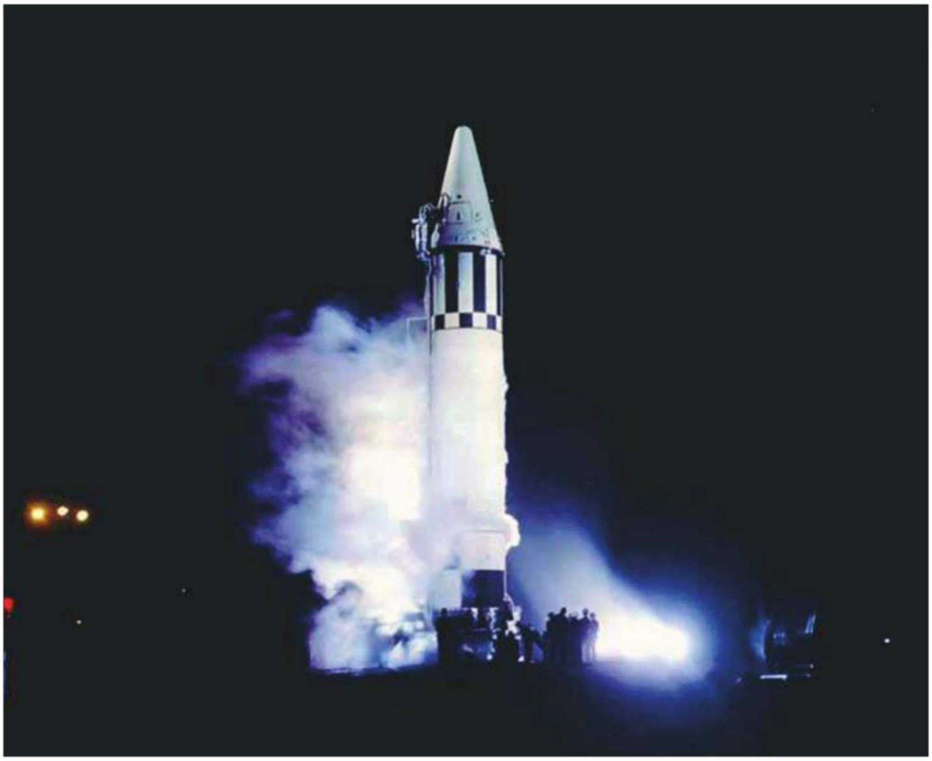
By the late 1940s it was clear that the facilities at Fort Bliss were no longer adequate for the US Army's ballistic missile research programme and it was decided to fully re-locate to the Redstone Arsenal in Huntsville, Alabama. The location allowed fairly easy access to the new test site at Cape Canaveral, Florida and on the 29th October 1949 von Braun's entire design team, about five hundred military personnel and roughly the same number of civilians, were moved to Huntsville. Von Braun was now married to his first cousin (Maria von Quistorp) while his good friend Walter Dornberger had been released into US custody and was working for a US defence contractor. This was undoubtedly due to intense lobbying by von Braun, who in 1950 had become head of the Army's Rocket Development Section.

The rocket group began work on a new missile called the Redstone, which stemmed from an earlier General Electric study known as SSM-A-13 Hermes C1. The requirement for the latest design was an ability to deliver a nuclear warhead over a distance of 500 miles (804km). There was now considerable pressure on the rocket group because the Korean War had started. This had the potential to expand into a Third World War and the CIA believed that the Russians were making good progress with their rocketry and nuclear capability. It also meant that plenty of funding was available for this project and design work for the SSM-A-14 Redstone was concluded in

Redstone Rocket undergoing assembly checks. US Army

Test firing of a Redstone missile, which evolved directly from the wartime V-2. US Army

A Jupiter IRBM undergoing tests prior to a night launch. US Army



1952. Chrysler was then contracted to prepare for production of the missile which was re-designated PGM-11A.

Redstone brought major advances including a separable warhead capsule and inertial guidance. Propulsion was provided by a North American Rocketdyne NAA75-110 (A-6) liquid-fuelled rocket engine (based on the Navaho design – see later) which produced a thrust of 78,000 lb (347kN). The PGM-11A had a (final) length of 69ft 4in (21.1m) and a core diameter of 5ft 10in (1.78m). Finspan was 12ft (3.66m) and the launch weight (depending on payload) was 61,000 to 62,000 lb (27,669 to 28,123kg). However, fitting Redstone with a heavy W-39 thermonuclear 4 megaton warhead effectively cut the missile's proposed range to about 249 miles (400km).

The first test launch took place at Cape Canaveral on 20th August 1953 but failed due to a control system malfunction, although subsequent launches proved successful and the Chrysler Corporation was issued with a production contract in 1955. Redstone entered service with the US Army's 217th Field Artillery Missile Battalion in 1956 and was eventually deployed to West Germany, but ground handling was complicated, it required many personnel and proved time consuming. Eventually the missile was replaced by the considerably more sophisticated and easier to use solid fuel MGM-31A Pershing. Meanwhile, Redstone had been adapted as the first stage booster for the Jupiter C (Juno 1) which placed the first small US satellite (Explorer 1) into orbit on 31st January 1958.

A further development was the Redstone-Mercury rocket which was used to launch a Mercury capsule containing astronaut Alan Shepard into space on 5th May 1961. This was only a sub-orbital flight because of the rocket's limited performance, but it was repeated on 21st July 1961 when Virgil Grissom became the second American in space. At last a rocket developed from von Braun's original design had lifted a man beyond the atmosphere.

Jupiter

The next project undertaken by von Braun's team was the development of an intermediate range ballistic missile (IRBM) called Jupiter. As the initial design work on Redstone moved towards its completion, the Ordnance Department requested a study into the possibility of developing a successor with a range of 1,000 miles (1,600km). Design work was already under way when President Eisenhower received a report from the Killian Committee in 1955 urging development of a new 1,500 mile (2,414km) ballistic missile to counter suspected developments in the Soviet Union. On 8th November 1955 US Secretary of Defense Charles E Wilson approved an IRBM for land and shipboard use by the Army and Navy, with development taking place at the Redstone Arsenal under von Braun. But this proved to be a poor decision as the US Navy soon rejected the idea of liquid fuels because it was already sold on the idea of a submarine-launched ballistic missile using solid propellant. As a consequence, the Navy withdrew from the new joint IRBM venture in 1956 to pursue the technically advanced Lockheed Polaris missile. Further political problems arose when Charles Wilson decided that the USAF (which was undertaking its own separate IRBM programme called Thor) should have sole responsibility for all long-range land-based missiles. While this was bad news for the Army, the Pentagon decided that von Braun's team should continue with its development of the Jupiter as an alternative to the USAF's troublesome Thor.

Throughout the remainder of the 1950s development of the SN-78/PGM-19 Jupiter was a politically sensitive issue as von Braun's team were now working on a missile that could not be used by the US Army. After two unsuccessful Jupiter launches at Cape Canaveral in early 1957 some minor changes were made to the design and the success rate improved considerably. The USAF was then requested to accept the Jupiter alongside the SM-75/PGM-17 Thor IRBM and in 1959 negations began with Italy and Turkey to deploy Jupiter missiles on their territory. The SN-78/PGM-19 Jupiter had an overall length of 60ft (18.3m) and a diameter of 8ft 9in (2.67m). Its launch weight was 110,000 lb (49,800kg) and the missile reached an altitude of 380 miles (611km) and a speed of Mach 13.5. Maximum range was about 1,976 miles (3,180km) and the Goodyear-built re-entry vehicle carried the very compact W-49 thermonuclear warhead with a 1.45 megaton yield. This warhead was also used on the Thor and the commonality of components didn't end there because the Jupiter's propulsion system was a kerosene and liquid oxygen Rocketdyne LR79-NA (Model S-3D) engine producing 150,000 lb (667kN) of thrust, the same unit fitted to Thor. However, Jupiter used the ST-90 inertial guidance unit which was judged to be more accurate than the Thor's unit. Jupiter also had the significant advantage over Thor of being a mobile system, making it more likely to survive an initial enemy strike.

However, Jupiter enjoyed a relatively short period of service with the USAF and, following the Cuba Missile Crisis of 1962, these missiles were withdrawn from Italy and Turkey as part of the deal between America and Russia. With the US Navy's Polaris now in service, the Jupiter was effectively obsolete. The USAF made some use of the Jupiter IRBM as a test vehicle launching two separate biological payloads (monkeys) into space during the late 1950s. Both missions were judged successful although the first capsule was not recovered. Jupiter missiles were also used as the first stage of the Juno II rocket. In total, Chrysler built about a hundred Jupiter IRBMs and this missile probably represents the ultimate development of the original von Braun A4 (V-2), although it could be argued that all post-war liquid fuel missiles and rockets have descended from the original German design.

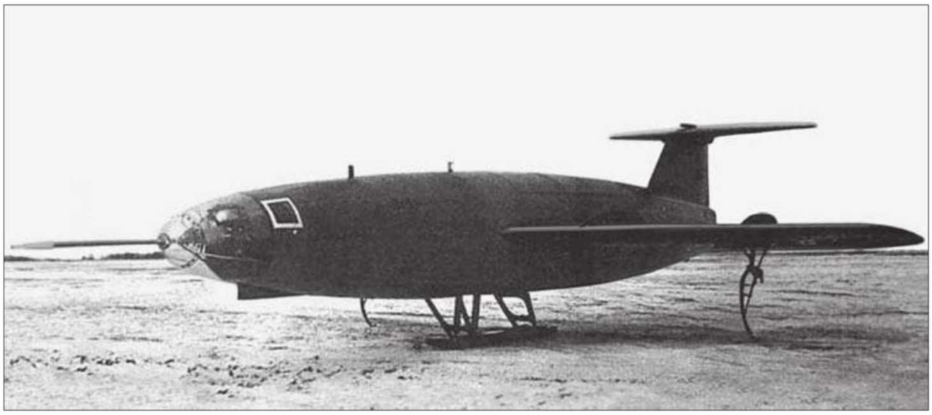
Rocketplanes

Development of America's first supersonic aircraft started during World War Two at the USAAF's Wright Field. The design group was initially steered by aerodynamicist Ezra Kotcher (1903-1990) but soon involved NACA Langley. It favoured jet propulsion but felt that gas turbine technology would be unable to deliver the power required for supersonic flight, so it was agreed that rocket motors were the only realistic choice. The resulting X-1 was based on the profile of a .50 calibre (12.7mm) bullet because this was one of the few shapes that provided data on supersonic flight when design work began in early 1944. However, there were substantial difficulties designing the wings and tailplane. Straight, thin wings were chosen although variations continued to be tested on wind tunnel models at NACA Langley. By 1947 swept wings were under consideration, but these were never used although they would become a feature of the USAF's next experimental rocketplane. The contractor chosen to manufacture the first three X-1 prototypes was Bell Aircraft Corporation located at Buffalo, New York, a company that had become America's leading developer of experimental military aircraft. Today Bell is best known as a manufacturer of helicopters, but in those days it held much the same status as Lockheed-Martin's Skunk Works or the Boeing Phantom Works. Development of this supersonic rocketplane was undertaken in total secrecy and remained that way, even after the X-1 had become the first aircraft to officially break the sound barrier.

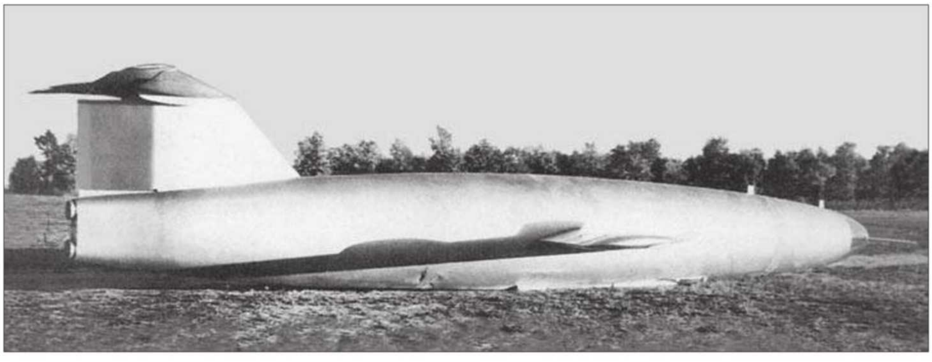
America was not the only nation working on supersonic flight. The Germans had been at the forefront of supersonic research and a rocket-propelled aircraft called the DFS 346 was under construction by the end on World War Two. DFS 346 was designed by Felix Kracht at the Deutsche Forschungsanstalt für Segelflug or DFS (the German Institute for Sailplane Flight) and the prototype was half-finished when the Russians captured it. The aircraft, its tools and documentation were then shipped to the Soviet Union where the prototype was completed and used for wind tunnel tests. This led to the construction of a more advanced slightly longer version of the aircraft that was simply referred to as the 346. The one-man 346 had a length of 44ft (13.4m), a wingspan of 29ft 6in (8.99m) and the first prototype was unpowered. Test flights began in 1947 with launches made from an impounded USAAF B-29 bomber. Two further examples were completed and 346-3 was equipped with a Russian-built liquid-fuel rocket engine. However, during a subsonic test flight in 1951 the German pilot Wolfgang Ziese lost control of the aircraft and, after he baled out, it was destroyed. At this point the 346 project was terminated. There have been claims that the Russians were the first to break the sound barrier with an aircraft based on the DFS 346, but this no longer appears to be the case.

The British were also working on a prototype supersonic research aircraft and hoped to use an advanced gas turbine for propulsion. During World War Two the Miles Aircraft Company was contracted to build three aircraft with the designation M.52. The design was created by Don L Brown and the company was assisted by the RAE and National Physical Laboratory. Like the Bell X-1, this aircraft was based on the ballistics of bullets. By the end of the war all three M.52 airframes had reached an advanced stage of assembly. The single-seat M.52 had a length of 28ft (8.5m) and a wingspan of 27ft (8.2m). It was expected to have a gross weight of 8,200 lb (3,720kg) and would be powered by an afterburning W.2/700 turbojet of 4,000 lb (17.8kN) thrust. A fully retractable tricycle undercarriage was fitted and the aircraft would make a conventional runway take-off. The design looked very promising but in 1946 the new Labour Government began to make dramatic budget cuts and the Director of Scientific Research, Sir Ben Lockspeiser decided he would scrap the M.52.

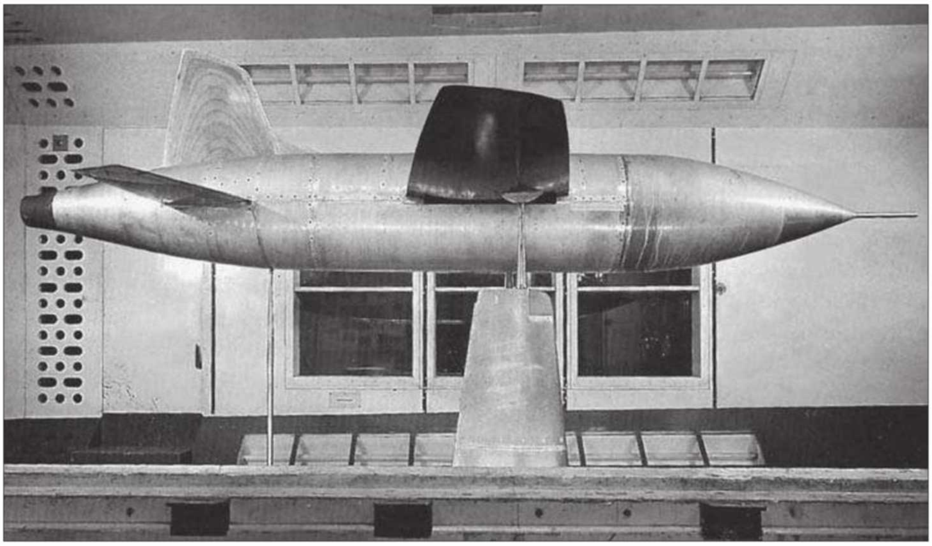
Although the project was largely paid for and had reached an advanced stage, various



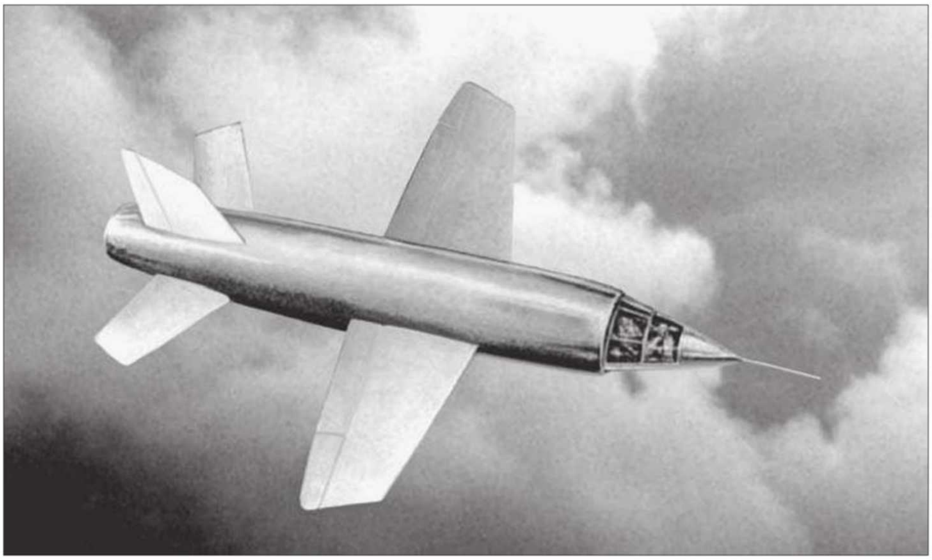
Prior to the Bell X-1 there were two European aircraft projects under way to break the sound barrier. One of these was the German DFS 346 designed by Felix Kracht. The prototype had not flown by the end of World War Two, but it was secured by the Red Army and returned to Russia.
Bill Rose



One of several Russian-built versions of the DFS 346 which were air dropped from an impounded B-29 Superfortress. This photograph is believed to show the 346-2 after a very hard landing on 30th September 1949 when the undercarriage collapsed. It was flown by German test pilot Wolfgang Zeise who was injured but made a full recovery. The aircraft was repaired.
Bill Rose



During World War Two the British Miles Aircraft Company was secretly contracted to build three experimental gas turbine-powered supersonic research aircraft designated M.52. This photograph shows one of the wind tunnel models. Miles Aircraft

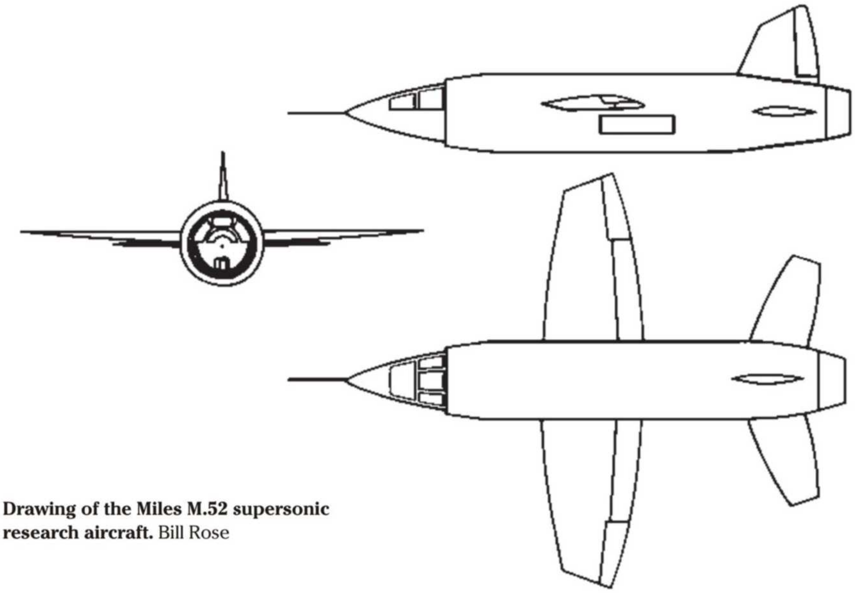


Representation of the M.52 in flight. Miles Aircraft

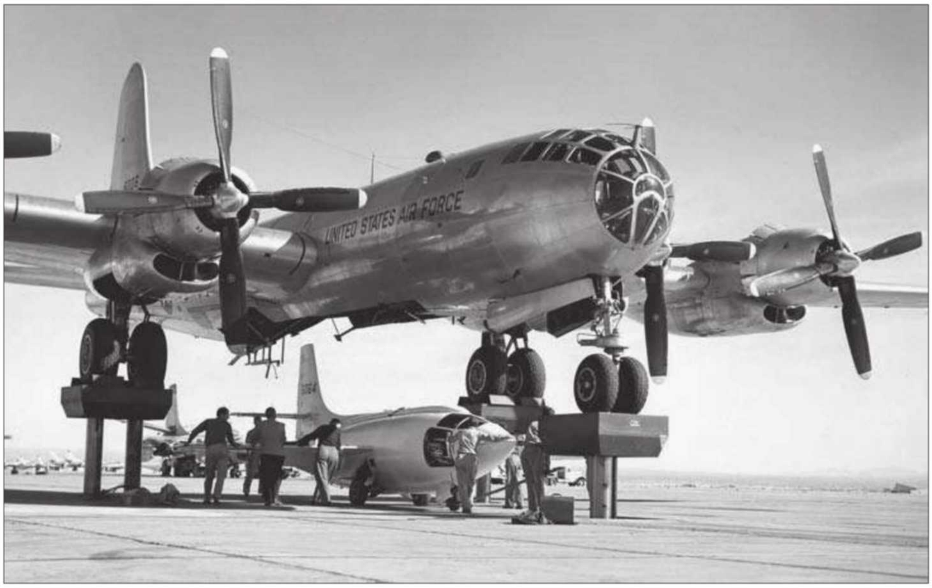
concerns were expressed by Lockspeiser about the hazards of breaking the sound barrier and pilot safety, which paved the way for the project's official cancellation. In fact the UK MoS had been doing some kind of behind the scenes deal with the Americans which meant that Britain would abandon its attempt to gain the record first and Bell would be provided with all the M.52 research data. In spring 1946 engineers from Bell secretly visited Miles and, according to Dennis Bancroft who was the company's chief aerodynamicist, it was agreed with MoS officials that the Americans would be provided with copies of all the M.52 documents. In return Miles would be given full access to the broadly similar Bell project within a fortnight. But this never happened and the M.52 was finally scrapped, with company officials being told that the jigs, tools and completed M.52 hardware had to be broken up. Just how useful the M.52 research was to the Americans remains a topic of debate amongst aviation historians, but the British seem to have received nothing in return for this favour.

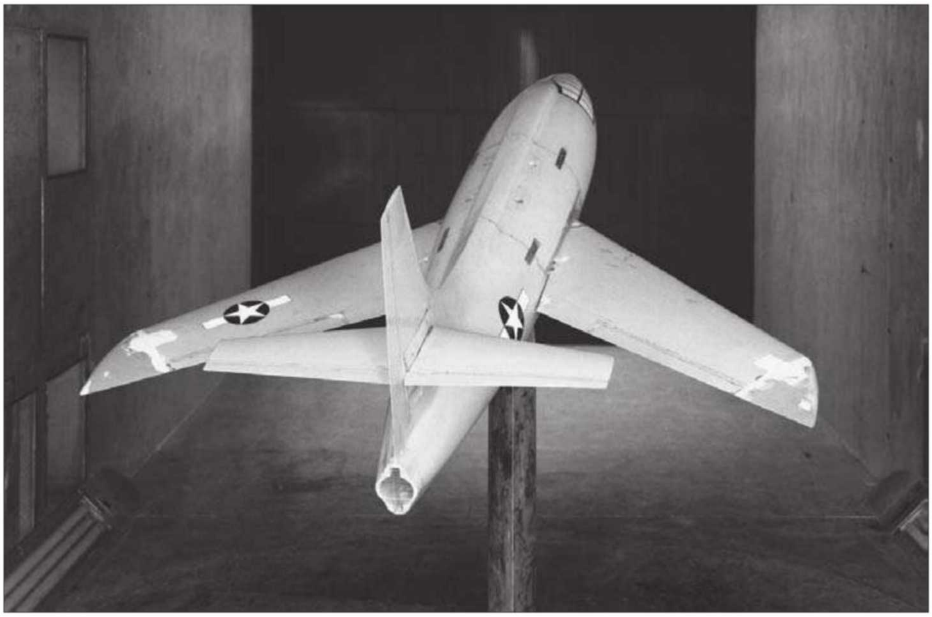
However, after the demise of the M.52, Vickers at Weybridge was commissioned to build a series of 11ft (3.35m) long models that were quite similar in shape to the M.52 under the direction of Barnes Wallis. Powered by a rocket engine developed at RAE, the first air-launch of Model A.1 was attempted from a modified Mosquito aircraft but ran into difficulties. The second launch on 8th October 1947 failed, but a third attempt on 10th October 1948 succeeded with Model A.3 reaching Mach 1.38. This validated the basic design and a relatively recent Rolls-Royce study indicated that the M.52 would have almost certainly achieved its objectives.

Back in the US unpowered test drops of the rocket-propelled Bell X-1 had begun in early 1946 using a converted B-29 bomber, and these trials proceeded fairly well with the first powered flight taking place during autumn 1946. Nevertheless, it would be another year before the first attempt to fly at supersonic speed was made. This happened on 14th October 1947 when X-1 serial 46-062, piloted by Chuck Yeager, achieved a speed of 700mph (1,126km/h) at 45,000ft (13,716m) above Muroc Dry Lake (now Edwards AFB). Details of the flight remained secret until the



Drawing of the Miles M.52 supersonic research aircraft. Bill Rose





magazine *Aviation Week* printed the story on 22nd December 1947, much to the USAF's anger. The exact reason for the secrecy has never been properly explained. The Bell X-1 had a length of 30ft 11in (9.4m), a wingspan of 28ft (8.5m) and a height of 10ft 10in (3.3m). Fully loaded the aircraft's gross weight was 12,250 lb (5,557kg) and it was powered by a liquid oxygen and alcohol Reaction Motors XLR-11-RM3 rocket engine which produced 6,000 lb (26.7kN) of thrust for five minutes. The maximum speed attained by an X-1 was 957mph (1,541km/h), although it was thought capable of attaining Mach 2.4, and the highest altitude reached was 70,000ft (21,336m).

The first X-1 (called *Glamorous Glennis* after Yeager's wife) is now on display at the National Air and Space Museum in Washington DC. A number of variants of the original aircraft were produced and these were flown until quite late in the 1950s. The Bell X-1B reached almost twice the speed of the X-1 and set an unofficial world altitude record of 90,440ft (27,566m) on 26th August 1954. Perhaps the most interesting un-built version was the Bell X-1C which would have been used to test machine guns and cannons at supersonic speeds. One of the most advanced proposals for a Bell X-1 variant featured swept wings and swept tail surfaces. It received the designation D-37 and underwent wind tunnel testing as a model, but it was never built.

The D-37 had drawn on research undertaken for an entirely new rocketplane called the Bell X-2 (below). The requirements for this next aircraft had actually been agreed between the USAAF, NACA and Bell during

The second Bell X-1 (46-063) rocketplane. NASA

The third Bell X-1 (46-064) is positioned beneath a Boeing EB-50 carrier aircraft. This aircraft was destroyed during a static test on 9th November 1951. NASA

Model of the swept wing Bell X-1. NASA

Following wind tunnel tests two Bell L-39 aircraft were used to develop the X-2's wing. Bell Aircraft

December 1945 and the formal contract (W33-038-ac-13835) was issued to Bell on 3rd July 1947. Bell had also been contracted to provide the US Navy with two propeller driven Bell P-63 Kingcobra fighters which had been fitted with swept wings and re-designated L-39. By now the US Navy was working on its own rocketplane programme (the Douglas D558-2 Skyrocket) and wanted to know more about the low-speed stability of swept wings. However, the L-39 proved very useful to the engineers working on the X-2 who were allowed to continue using it for research purposes when the Navy concluded their part of this programme in July 1946.

Douglas Rocketplanes

The US Navy's Bureau of Aeronautics began work on its post-war experimental high-performance aircraft programme with the subsonic Douglas D-558-I Skystreak that had been designed in 1945 as a turbojet powered test-bed. The single-seat D-558-I was powered by an Allison J35-A-11 turbojet engine that produced 5,000 lb (22kN) of thrust. It had a length of 35ft 8in (10.8m), a wingspan of 25ft (7.62m) and a height of 12ft (3.65m). The maximum take-off weight was 10,105 lb (4,583kg) and the D-558-I was supported by a tricycle undercarriage. Three aircraft were built and delivered to Muroc for US Navy and NACA test-flights, which continued until 1953. However, these trials were not without serious incident and the second Skystreak was lost in an engine related accident on 3rd May 1948 which killed the test pilot. There was an option to build three further D-558-I aircraft, but this was not taken up due to the rate of technical progress which had made the design obsolete. The D-558-I was a straight winged, rather non-descript aircraft and official attention remained focused on the USAF's rocket powered Bell X-1. Nevertheless, the Douglas D-558-I briefly held several speed records and provided a great deal of useful aerodynamic research data.

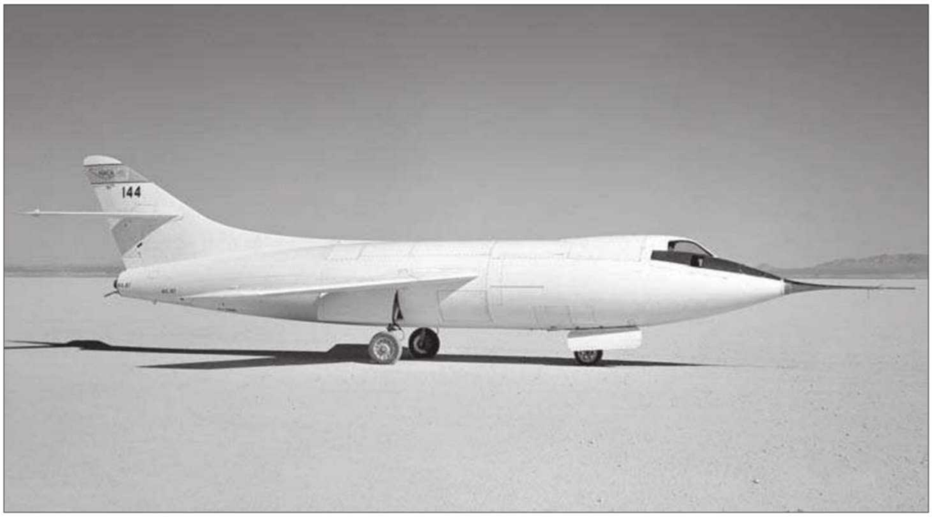
The next phase in the Navy's programme saw the arrival of a more advanced Douglas-built swept-wing one-man supersonic research aircraft. Known as the D-558-II Skyrocket, this had a length of 42ft (12.8m) a wingspan of 25ft (7.6m) and a height of 12ft 8in (3.86m). Mainly constructed from aluminium and magnesium, three copies of the D-558-II were provided to the US Navy. The first (NACA designation 143) was powered by a totally inadequate Westinghouse J34-40 turbojet which provided a thrust of 3,000 lb (13.3kN), and so because of this rocket assistance was required during take-off. In late 1954 Douglas modified this aircraft and replaced the turbojet with a non-throttable four-chamber Reaction Motors LR-8-RM-6 engine (the same power unit used in the Bell X-1E variant) which provided 6,000 lb (27kN) static thrust at sea level. The second D-558-II (NACA 144) was fitted with an LR-8-RM-6 liquid-fuelled rocket engine and was used as an air-launched rocketplane. Skyrocket launches were carried out at an altitude of about 30,000ft (9,144m) using an extensively modified Boeing P2B-1 Superfortress (the Navy's version of the B-29). The P2B-1 (84029) was named 'Fertile Myrtle' and assigned NACA designation 137. The third Douglas D-558-II (NACA 145) was equipped with an LR-8-RM-5 rocket and a Westinghouse J-34-40 turbojet. It was mainly used to gather data on the behaviour of external stores at transonic speeds.

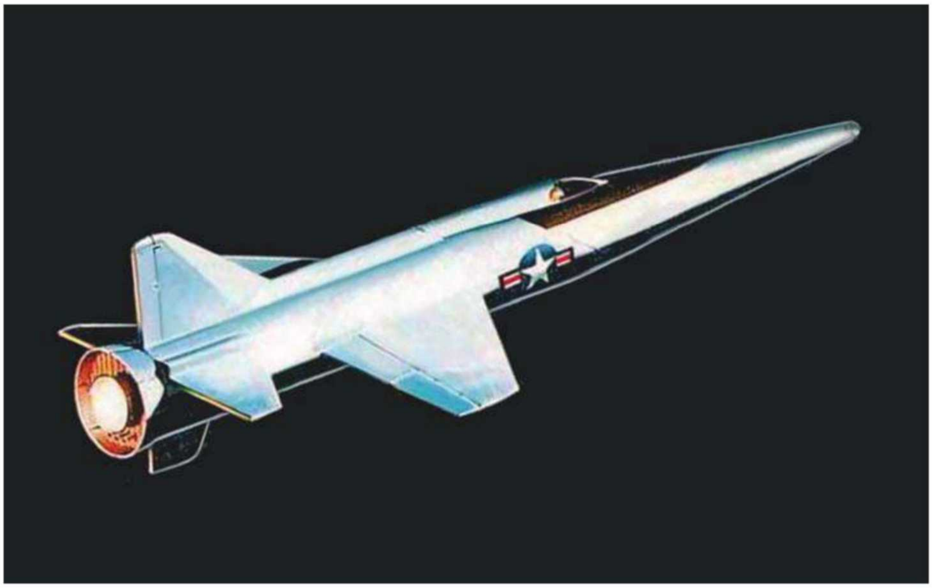
The first D-558-II made its initial flight at Muroc on 4th February 1948 and was flown by Douglas's test pilot John Martin. The first air-launch of a D-558-II took place on 8th September 1950. On 21st August 1953 US Marine test pilot Marion Carl increased the aircraft's existing unofficial altitude record to 83,235ft (25,370m), and on 20th November 1953 NACA test pilot Scott Crossfield attained the distinction of flying a Skyrocket at twice the speed of sound (Mach 2) for the first time. These two achievements were probably quite close to the limits of the D-558-II's capability and most of the test programme was taken up with examining transonic aerodynamic phenomena, with particular emphasis on pitch-up problems. The three Skyrockets flew a total of 131 sorties during the programme, which was concluded in December 1956.

Two different options were considered for the next phase of this test programme. The first would have involved the construction of a mock-up of a combat aircraft utilising features based on research carried out with the D558-1 and D-558-II. This never took place and was probably considered unnecessary as there were now many programmes under way to develop new systems for high performance combat aircraft. A more interesting proposal was made by Douglas to build a hypersonic aircraft designated Model 671 or D-558-III and given the name Skyflash. This would have been a Navy equivalent of the USAF's North American X-15 rocketplane with a design ceiling of about 700,000ft (132 miles/213km) – which would have earned the pilot astronaut's wings. A one million dollar one-year study was initiated in 1954 which led to the wind tunnel testing of models. The aircraft would have a length of 47ft (14.3m), an overall height of 13ft (3.96m) and its unswept but tapered wings would have a span of 18ft (5.48m). Maximum launch weight would be 22,000 lb (9,976kg) of which 15,000 lb (6,803kg) was fuel.

The rocket engine selected for Skyflash would be the new Reaction Motors XLR-30-RM-2, running on ammonia and liquid oxygen to produce 50,000 lb (222.4kN) of thrust. Skyflash would be launched by a Boeing B-52 carrier aircraft travelling at Mach 0.75 and 40,000ft (12,190m). After separation the

Three turbojet-powered Douglas D-558-I Skystreaks were built as research aircraft for the US Navy and NACA in the late 1940s, although the rate of technical advancement soon made them obsolete. NASA





The Douglas D-558-II Skyrocket was an advanced swept-wing supersonic research aircraft built for the US Navy and NACA. Three examples of the D-558-II were completed with different propulsion systems. NASA

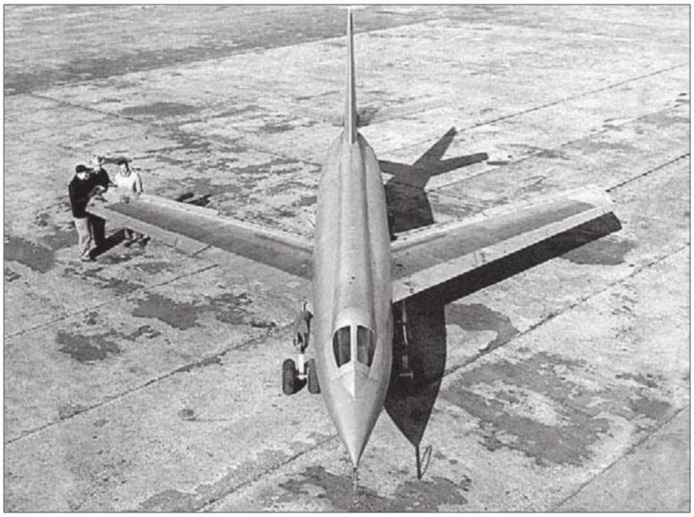
The second D-558-II (NACA 144), powered by a liquid fuel rocket engine, is launched from a modified US Navy P2B-1s Superfortress. NASA

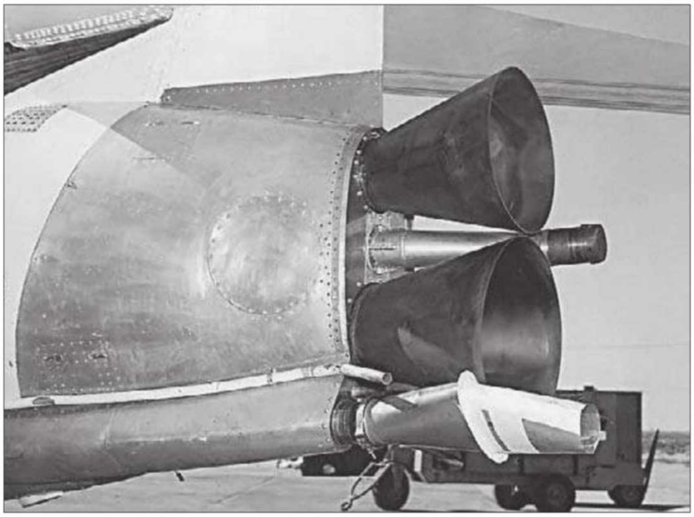
Intended as a hypersonic successor to the D-558-II, the Douglas Model 671 or D-558-III Skyflash would have probably outperformed the USAF's X-15. Douglas Aviation

rocketplane's pilot would ignite the engine and pull up into 38° climb and the engine would run at full throttle for seventy-five seconds. In addition to control surfaces for use within the atmosphere, the Skyflash would also be equipped with a reaction control system using hydrogen peroxide for exoatmospheric manoeuvring requirements. High temperature materials would be used in key areas of the design and during the descent it was anticipated that the rocketplane would briefly reach Mach 9 to 10. Skyflash would finally glide to the landing site and use a tricycle undercarriage for touchdown. Edwards AFB was regarded as the most likely launch and recovery location and there is reason to believe that the Douglas Skyflash might have achieved more than the rival X-15. However, the Navy was wary about funding a potentially very expensive project on the fringes of its normal interests and decided to abandon further development in 1955.

Bell X-2

Two Bell X-2 prototypes (46-674 and 46-675) were built at Bell's Niagara Falls plant and the second aircraft was finished first. With concerns about the 'thermal barrier' being the next high-speed challenge (where the build-up of heat from air friction would affect the airframe), the new aircraft was fabricated from stainless steel and K-Monel (nickel-copper) alloy. The aim of this new rocketplane was to reach Mach 3 and exceed a ceiling of 100,000ft (30km). The X-2 was originally intended to use a rocket engine developed by Bell but the development of the liquid fuel engine was assigned to Curtiss-Wright for financial reasons. On paper the Curtiss-Wright XLR-25 proposal looked very good. It was a throttleable two-chamber design providing 2,500 to 15,000 lb (11 to 66.7kN) of thrust. Unfortunately, Curtiss Wright had little experience with rocket propulsion and was virtually starting out from scratch. Consequently, there were endless engineering problems, explosions at the test stands and design faults that seriously delayed the X-2 programme.





The single-seat X-2 had an overall length of 37ft 10in (11.5m), a wingspan of 32ft 3in (9.8m) and a height of 11ft 10in (3.6m). Fully fuelled its launch weight was 24,910 lb (11,300kg). Saving weight and maximising the use of internal space were major considerations so the X-2 did not have a proper undercarriage as such and used a nosewheel and retractable skids for landing. However, landings were not without incident and rarely went according to plan. While the X-2 was on the ground, a special custom built dolly was used to move it.

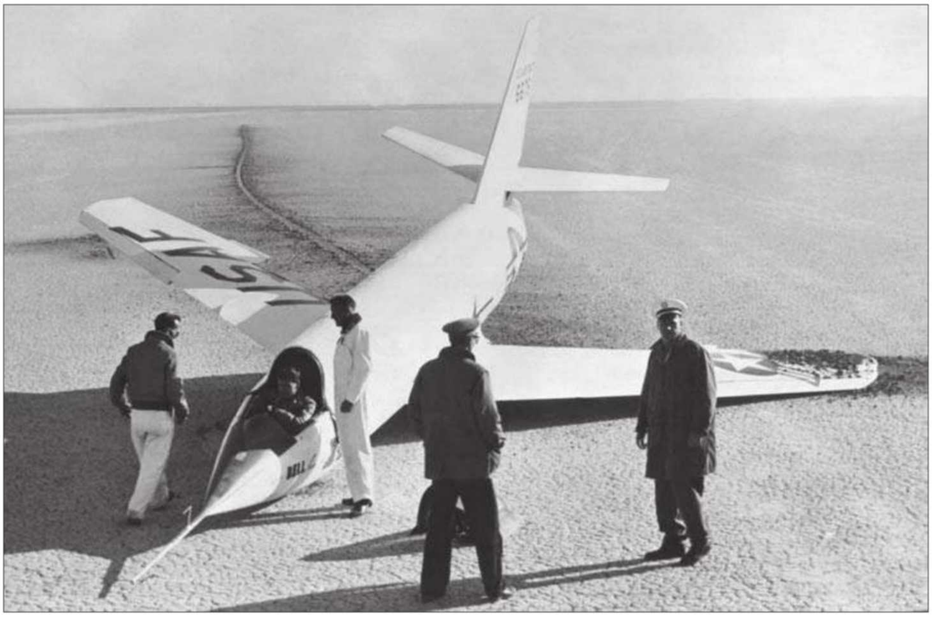
On 27th June 1952 Bell test pilot Jean 'Skip' Ziegler made the first glide flight in the X-2 (46-675) after being released from a Boeing EB-50B carrier aircraft above Edwards AFB. Two further un-powered test-flights followed. Then on 12th May 1953 while the X-2 and its carrier were performing captive fuel dump trials over Lake Ontario, there was an explosion which killed Ziegler and an observer. What remained of 46-675 was dumped into the lake and the EB-50B managed to return to base to make an emergency landing. Eventually, the cause of the explosion and fire was traced to a leather gasket which had reacted to liquid oxygen. In fact components made in this organic material also caused the loss of an X-1, an X-1A and an X-1D, in each case after reacting with liquid oxygen.

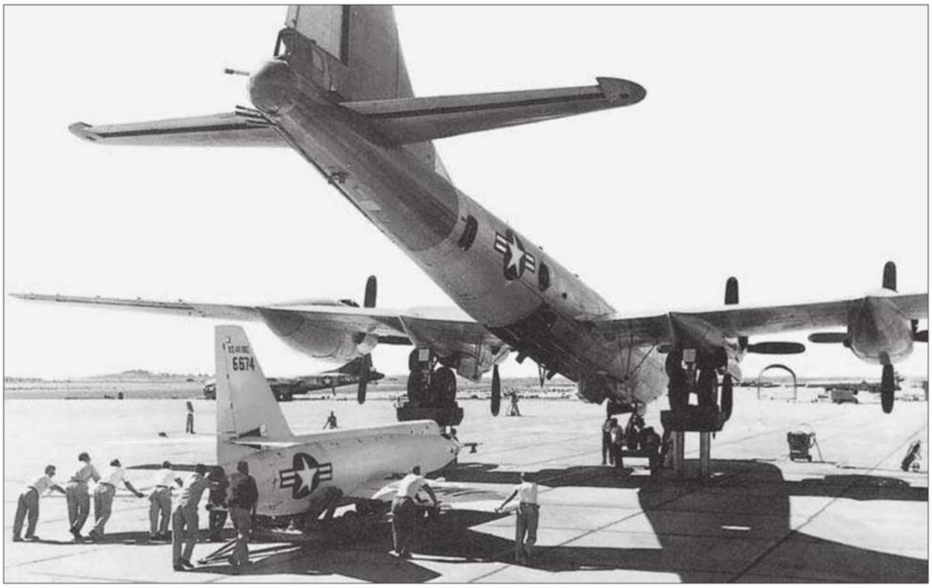
The unpainted Bell X-2 (46-675) after roll out in November 1950. Bell Aircraft

The Curtiss-Wright XLR-25-CW two-chamber rocket engine with exhaust expansion nozzles was fitted to X-2 46-674 for its final flights. NASA

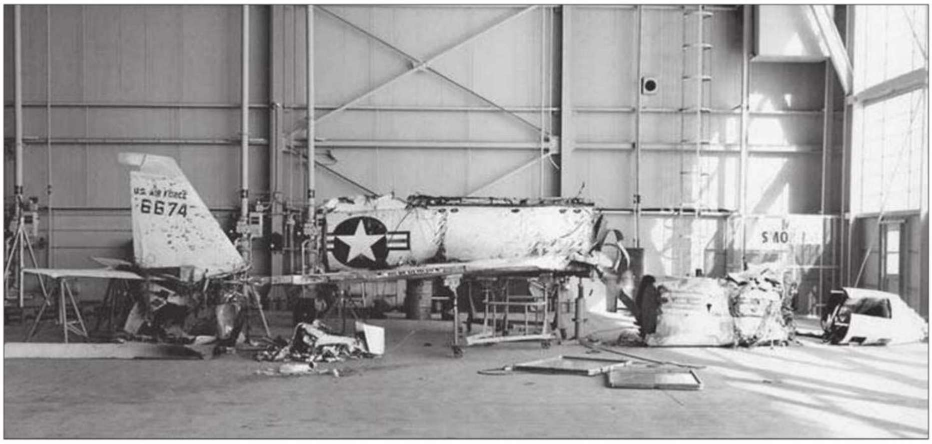
Making a glide landing in the Bell X-2 was always difficult, as this photograph shows. NASA

X-2 46-674 on its ground-handling unit is rolled into position beneath the elevated EB-50D carrier aircraft. NASA

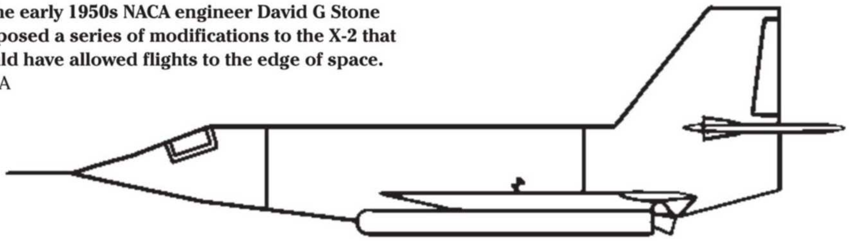




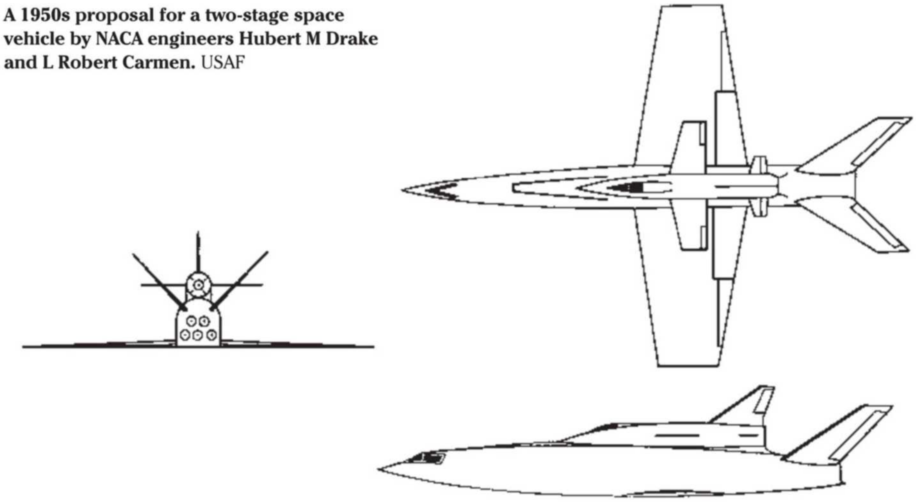
46-674 prepares to land. Note that some areas of the fuselage appear to have been superficially damaged. NASA



The wreckage of X-2 46-674 is assembled in a hanger for investigative purposes. This second fatal accident brought the programme to a conclusion. NASA



In the early 1950s NACA engineer David G Stone proposed a series of modifications to the X-2 that would have allowed flights to the edge of space. NASA



A 1950s proposal for a two-stage space vehicle by NACA engineers Hubert M Drake and L Robert Carmen. USAF

Despite the accident, testing continued and USAF pilot Lt Col Frank 'Pete' Everest made the first powered flight in the second X-2 on 18th November 1955. He continued to fly the aircraft for several months, achieving a speed of Mach 2.8 on his last flight during July 1956. USAF Captain Iven Kincheloe was then assigned to the project and he flew the X-2 to an altitude of 125,907ft (38,376m) on the 23rd July 1956.

After four flights Kincheloe was replaced by USAF Captain Milburn Apt who had been briefed to fly an 'optimum energy flight path'. On 27th September 1956 after being dropped from the EB-50A, Apt climbed to 70,000ft (21,330m) and reached a speed in excess of Mach 3 to become the fastest man on Earth. Then for some inexplicable reason, Apt began to bank and the X-2 started to tumble. Inertia coupling took effect and, despite the fact that he was a very experienced test pilot, Apt lost control of the aircraft and attempted to eject. This proved unsuccessful and he was still in the cockpit when the aircraft crashed in the desert. Apt was killed instantly and the X-2 was destroyed.

By now there was now a hypersonic aircraft project under way and so the X-2 programme was closed. However, the X-2 resurfaced in the 1980s when an accurate mock-up of this aircraft was built and used in several productions filmed at Universal Studios in Hollywood. These included *The Right Stuff* and the TV series *Quantum Leap*. There had been early ideas to extend the capability of the Bell X-2 much further and perhaps give it the ability to climb all the way into orbit. It is also said that the USAF expressed an interest in developing a version of this aircraft to overfly parts of the Soviet Union on photo-reconnaissance missions.

The proposal to upgrade the Bell X-2 to a space vehicle came after two different studies were put to NACA for experimental high-performance rocket aircraft. The first came from Walter Dornberger and his colleague Krafft Ehricke who worked for Bell. They hoped to move Eugen Sänger's research forward using the skip-glide principle and had begun to develop a delta winged two-stage rocket bomber for the USAF. There would also be a variant of the design to use for research purposes. Promoted to NACA by Bell's chief engineer Robert J Woods, the Dornberger-Ehricke study generated considerable interest within NACA's High Speed Flight Research Station (HSFRS) at Edwards AFB.

As a consequence, Hubert M Drake and L Robert Carmen, who were engineers based at HSFRS (later the NASA Dryden Flight Research Center), began detailed studies of an equivalent two-stage rocketplane system. This utilised a large supersonic manned carrier aircraft which launched a smaller rocketplane. Separation would take place at an altitude of about 50,000ft (15,240m) and a speed of Mach 3. They believed that the second stage would be capable of Mach 10 and could reach 1,000,000ft (189 miles/304km). The Drake-Carmen manned launch vehicle would be 100ft (30.48m) in length with a wingspan of 66ft (20.1m). It would have a butterfly (V-shaped) tail and there would be five rocket engines for propulsion. The manned upper stage would be approximately 46ft (14m) long and have a wingspan of 20ft (6m). It would be propelled by a single liquid oxygen and alcohol-fuelled rocket engine that was designed to burn for one minute.

The evaluation of these two different proposals was passed to David G Stone who headed the Stability & Control Department of NACA Langley's Piloted Aircraft Research Division (PARD). Stone studied the ideas in detail and then came up with a third suggestion to modify the Bell X-2 and make it space-capable. Although the X-2 programme was still at an early stage, Stone proposed the attachment of two jettisonable JPL-4 Sergeant solid fuel rocket motors to act as boosters after the X-2 had been dropped from the launch aircraft. The X-2 would also be modified to include a reaction control system in the nose, tail and wingtips to provide control above 200,000ft (60km). Stone argued that the X-2 was an affordable way to produce an air-launched spaceplane capable of flying at speeds above Mach 4.5 at altitudes in excess of 300,000ft (91,400m), and to ultimately achieve orbit.

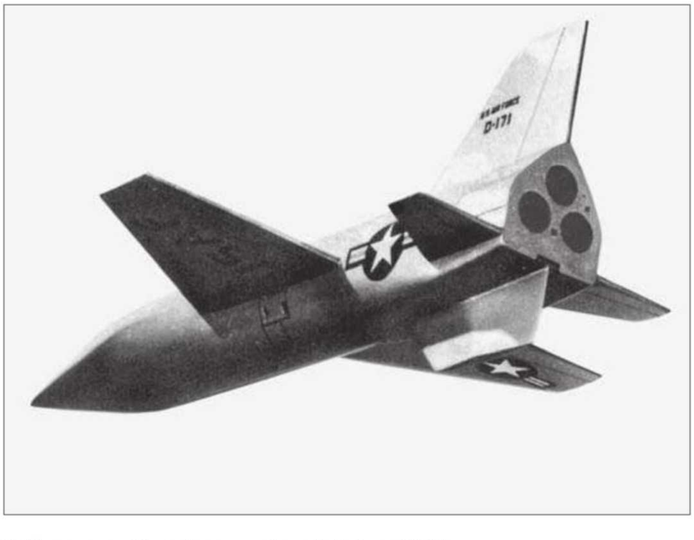
Stone's suggestions were put to NACA's influential Brown Group which had been made responsible for hypersonic flight projects. The Group comprised Clinton E Brown from the Compressibility Research Division, Charles H Zimmerman from the Stability and Control Division, and William J O'Sullivan from the Pilotless Aircraft Research Division. By late 1953 the Brown Group concluded that Stone's advanced X-2 was the most practical of the three proposals and they approved further engineering studies. However, an Inter-Laboratory NAC meeting held in Washington DC on 4th and 5th February 1954 finally rejected the X-2 spaceplane on the grounds that the vehicle was too small, and recommended development of a larger rocketplane that was designed from the outset for hypersonic research. The advanced X-2 project was now at an end and the next step for NACA would be the North American X-15.

North American X-15

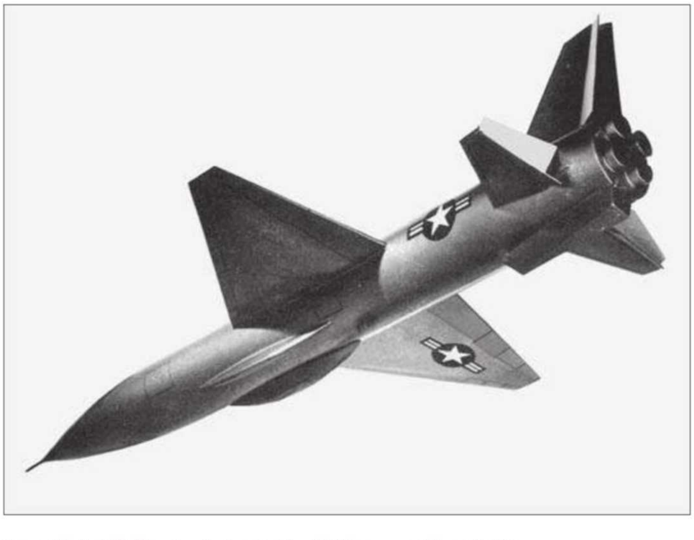
The North American X-15 represented a significant step forward from the Bell X-2 and provided the USAF and NACA with the world's first hypersonic (Mach 5+) manned aircraft. Three one-man X-15s were built and between 1959 and 1968 they completed 199 flights. The air-launched X-15s set numerous speed and altitude records, which included thirteen flights above 50 miles (80km) that qualified as space missions and earned the pilots astronaut's wings. Two of these flights exceeded an altitude of 62.1 miles (100km) and were accepted under the international FAI definition for spaceflight.

After the Brown Group recommended the development of a hypersonic aircraft, various defence contractors were asked to submit plans and the choice was soon narrowed down to four different designs. Initially, the leading concept came from Bell who proposed an aircraft with many hallmarks of a next generation X-2. It had a similar overall length to the X-2 but had a shorter 25ft 6in (7.7m) wingspan and a substantially more powerful rocket engine. In second place was a design from Douglas who was already working on a hypersonic aircraft called the Model 671 for the Navy. In moderately revised form this concept was submitted to NACA as the Model 684. In third place was a slightly larger design from Republic called the AP-76 that evolved alongside the company's experimental high performance XF-103 turboramjet interceptor, which was under development for the Air Force. The final proposal submitted to NACA came from North American Aviation based in Los Angeles who produced a study designated 7487.

Although it is probable that any one of these designs could have been developed into a successful test vehicle, the North American rocketplane was finally selected in September 1955. Part of the reason for this was North American's superior choice of construction materials for specific parts of the airframe, such as titanium and the nickel superalloy Inconel-X. The X-15 would be air launched and the chosen carrier aircraft was initially a converted Convair B-36 bomber, to be followed by an adapted Boeing B-52. However, another option that remained under consideration was the Convair B-58 Hustler bomber and it was thought that an unmodified X-15 launched at supersonic speed from this aircraft might attain Mach 7.6. North American received a formal contract from the



Bell's proposal for a hypersonic rocketplane. NASA

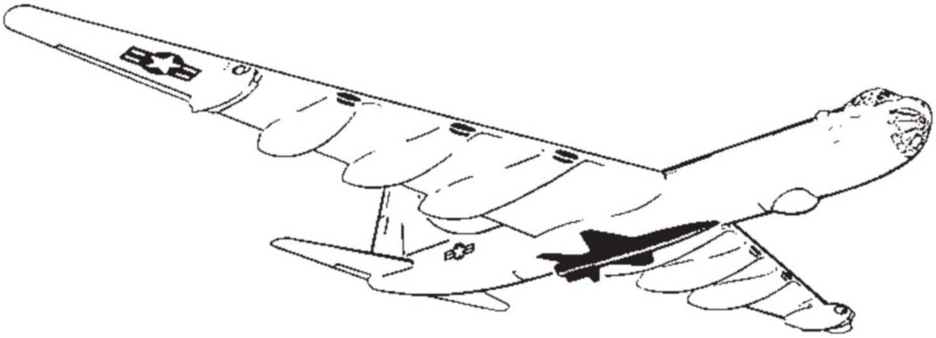


Republic's AP-76 submission to the X-15 competition. NASA

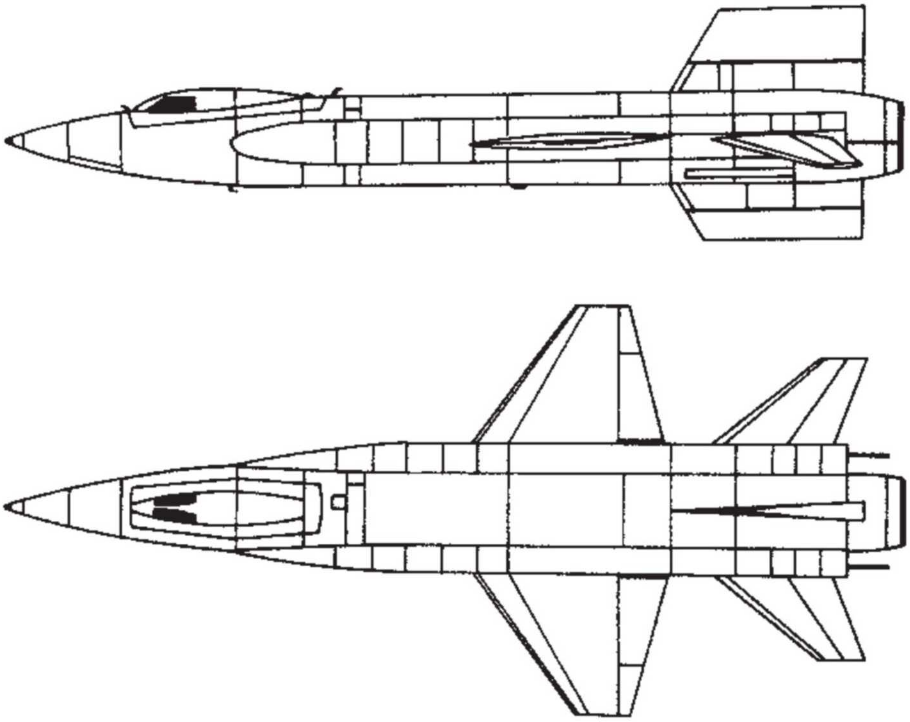
USAF (AF-33(600)-31693) to begin construction of three X-15s while another contract for their rocket engines was issued to Reaction Motors (a division of Thiokol Chemical Corp) in early 1956.

Heading the North American X-15 design team was Charles Feltz and Harrison Storms, who were supported by NACA scientists at Langley and Dryden. They had been aware from the outset that thermal considerations were the primary issue and some parts of the aircraft such as the nose and leading edges of the wings would reach temperatures as high as 1,240°F (671°C). To combat these problems much of the airframe was manufactured from titanium, with the key hot areas covered in Inconel-X. There was no mistaking the design of the X-15 for anything other than an experimental rocketplane. The cylindrical fuselage was approximately 50ft 9in (15.46m) in length (this varied slightly depending on nose boom or engine installation), the short stubby wings had a span of 22ft 4in (6.8m), wing area was 200ft^2 (18.6m^2) and the X-15 had an overall height of 13ft 6in (4.12m). Gross weight at launch was 31,275 lb (14,186kg), dropping to 12,295 lb (5,576kg) at the end of a powered flight.

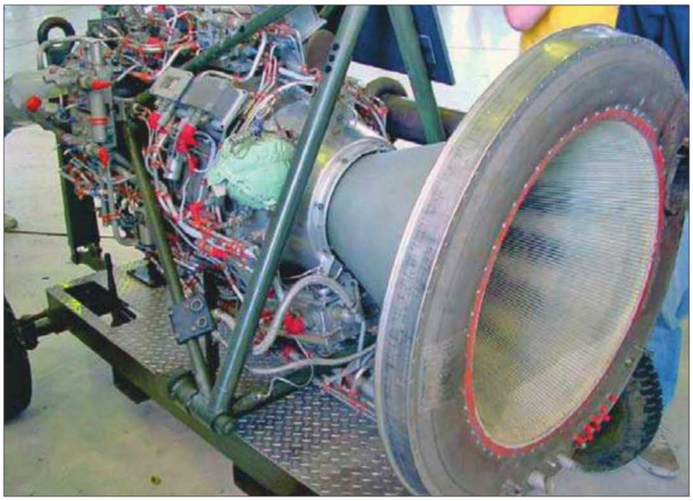
The chosen powerplant was a Reaction Motors XLR-99 rocket engine fuelled with ammonia and liquid oxygen. This complex and sophisticated piece of engineering was designed to be throttleable and produce a maximum thrust at sea level of 57,000 lb



An early suggestion was to adapt a B-36 bomber as the carrier aircraft for the X-15 rocketplane. USAF



North American X-15 drawing. USAF



The advanced Thiokol XLR-99 rocket engine used to propel the North American X-15. NASA

X-15 (66671) under rocket power. NASA

(253.5kN). Hydrogen peroxide was used to power the turbopump system that fed the engine in a similar fashion to that pioneered by the Germans for the A4 rocket. An XLR-99 was expected to have a service life of one hour, which needs to be seen in context because during a test flight the engine would only burn for around eighty plus seconds until the fuel was exhausted. However, the XLR-99 took a considerable effort to develop and was not available for early flight-testing, so initially the X-15 was flown with two XLR-11 engines producing a thrust of 16,380 lb (72.8kN). The X-15 used conventional control surfaces for atmospheric flight and a reaction control system at extreme altitude. The preferred landing site was Rogers Dry Lake close to Edwards AFB, although there were several alternatives available for emergency use. To minimise weight the X-15's landing gear comprised an extendable nosewheel and skids, with the lower tail fin having to be jettisoned before the aircraft touched down because it would have extended below the skids.

The first X-15 flight was made by Scott Crossfield on 8th June 1959, although this was just a glide drop from the B-52 carrier aircraft. Crossfield also made the first powered flight on 17th September 1959, which remained subsonic. Unfortunately, the first XLR-99 was not available until a year later when it was used for the first time on 15th November 1960. Another year after that and the X-15 had reached Mach 6 and attained an altitude of 217,000ft (66,000m). In all twelve test pilots flew the X-15, including Neil Armstrong who became the first man to set foot on the Moon. The programme was extremely successful but there were two serious accidents, one of which proved fatal. The first took place on 9th November 1962 when the second X-15 suffered an engine failure. NASA pilot Jack McKay was unable to eject and had to make an emergency landing at Mud Lake, Nevada in a seriously overweight condition. This made the landing gear collapse and the X-15 turned over. McKay was quite badly injured and the X-15 was virtually a write-off, but

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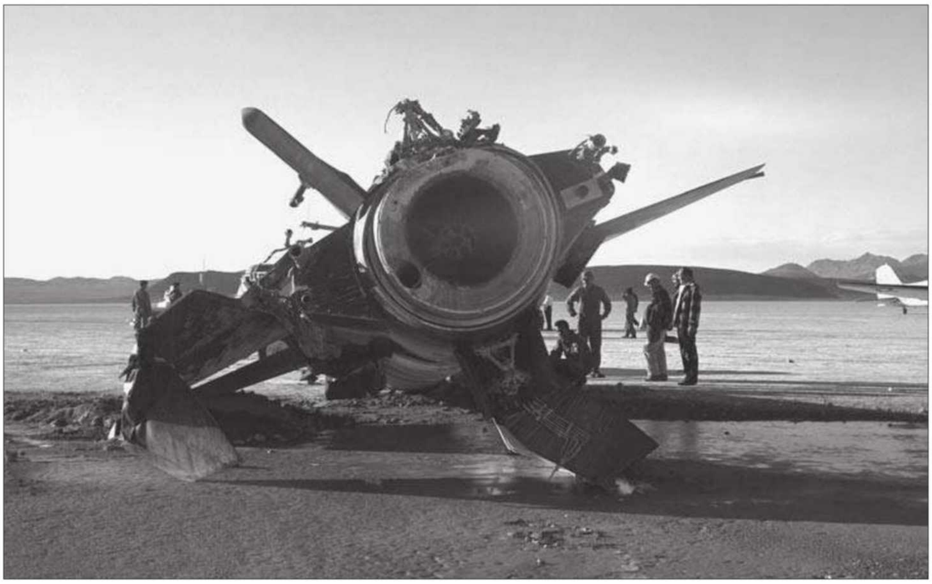
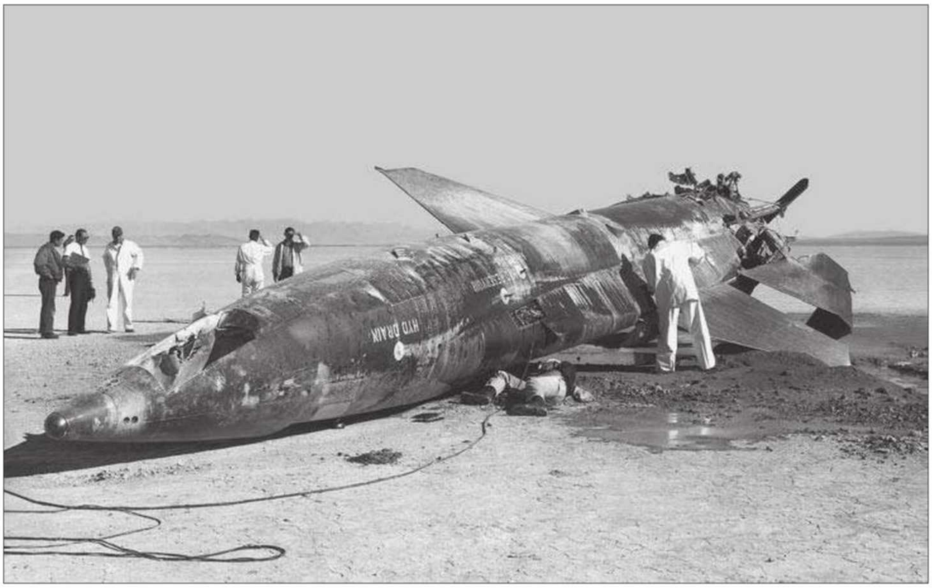
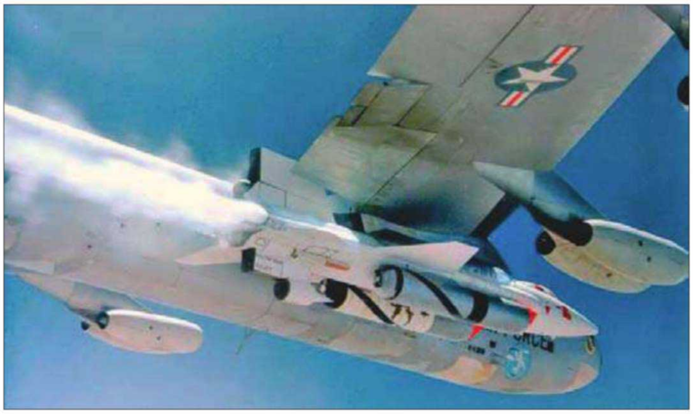
A spectacular view of the X-15 flying on rocket power. NASA



Following an engine failure the second X-15 made an emergency landing at Mud Lake on 9th November 1962. The overweight rocketplane was seriously damaged and NASA pilot Jack McKay was injured in the crash. The aircraft was salvaged and re-built by North American as the X-15A-2.

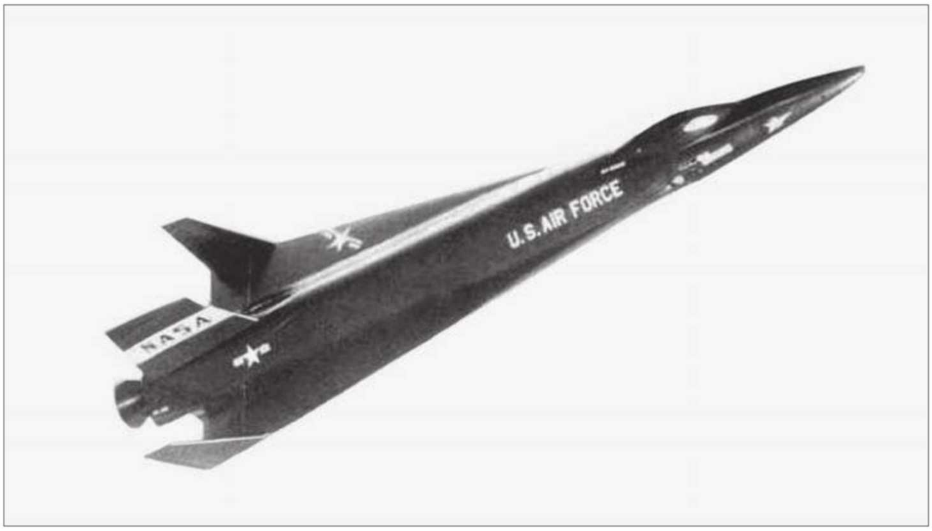


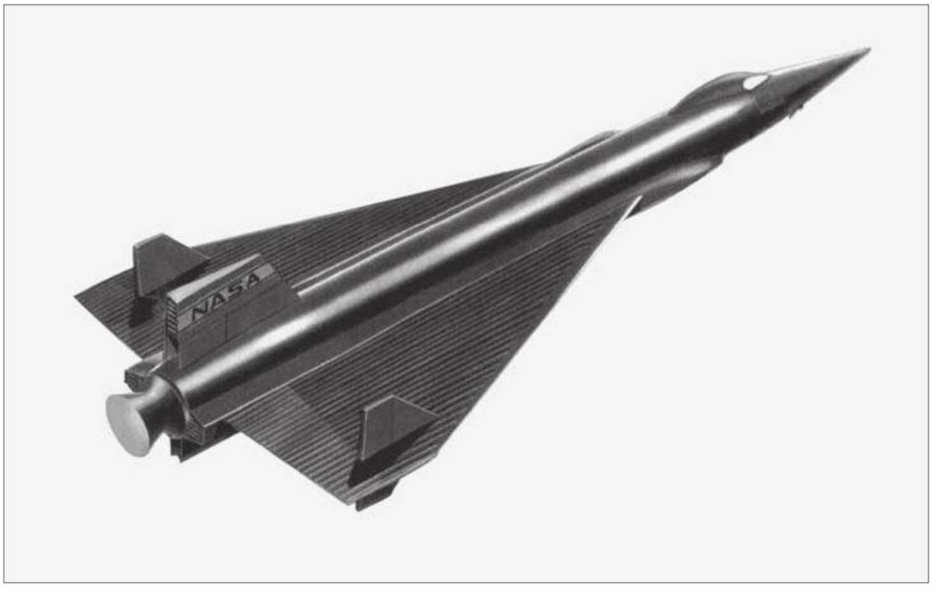
Engineers inspect the wreckage of the second X-15 after its crash landing at Mud Lake on 9th November 1962. NASA



North American was able to salvage some of the parts and use them to construct what was essentially a new aircraft.

However, worse was to come on 15th November 1967 when Michael Adams lost control of the third X-15, which became unstable after re-entry. The aircraft soon exceeded 15G, well beyond the stress limit of +7.3G and –3G, which caused it to break up in flight. Parts of the X-15 were scattered across an area of some 50 square miles (129.5km^2) and Adams was killed.





X-15A-2

The second X-15 was completely rebuilt after the Mud Lake accident, using some of the recovered parts, but when complete it was virtually a new higher performance vehicle. As the X-15A-2 it was approximately 2ft 2in (670mm) longer and had been equipped with jettisonable external fuel tanks providing approximately another sixty seconds of powered flight. The landing gear was improved, a new ablative external surface was applied to counter re-entry heating and the X-15A-2 was fitted with an XLR-99 rocket engine. The X-15A-2 first flew on 28th June 1964 and it was hoped that it might eventually achieve Mach 7.

On 3rd October 1967 the X-15A-2, piloted by William J Knight, reached a speed of Mach 6.7 at an altitude of 102,100ft (31,120m) to set a new world speed record. But a dummy ramjet unit became detached and the ablative layer proved ineffective, leading to structural damage. As a consequence the X-15A-2 never flew again. In fact the modifications had only proved partly successful because the extra fuel tanks had added 57,000 lb (25,854kg) to the launch weight and generated considerable drag. The ablative material was also largely ineffective and this coating required hundreds of man-hours to strip and replace it.

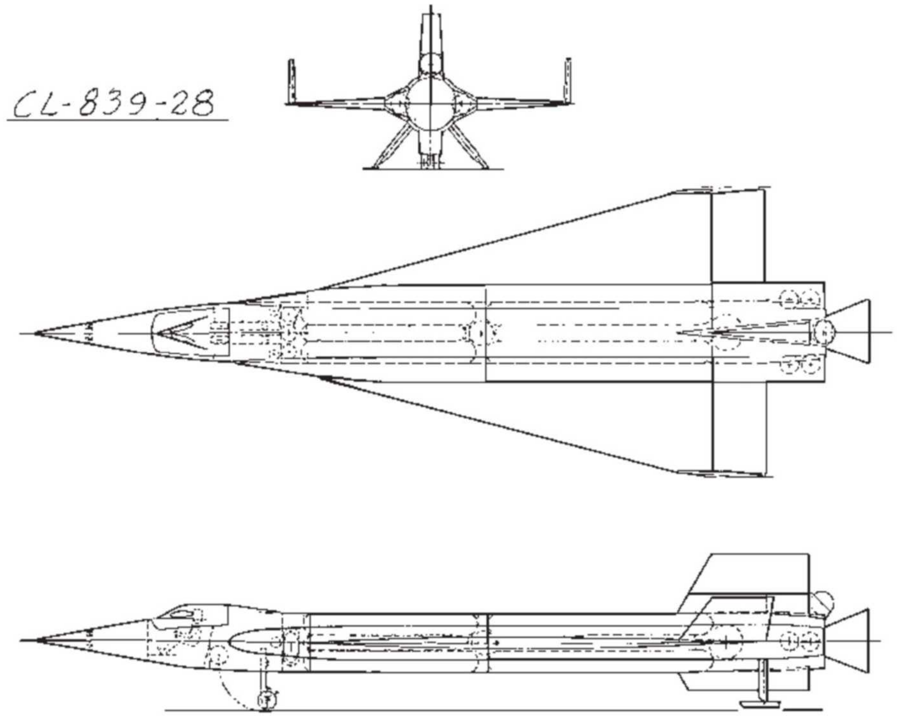
Many proposals were considered for advanced versions of the X-15 and, at one

Top left: **The X-15A-2 with unusual ablative external coating and drop tanks is prepared for release. On 3rd October 1967 it reached a speed of Mach 6.7, at an altitude of 102,100ft (31km), to set a new world record, but was damaged in the process.** NASA

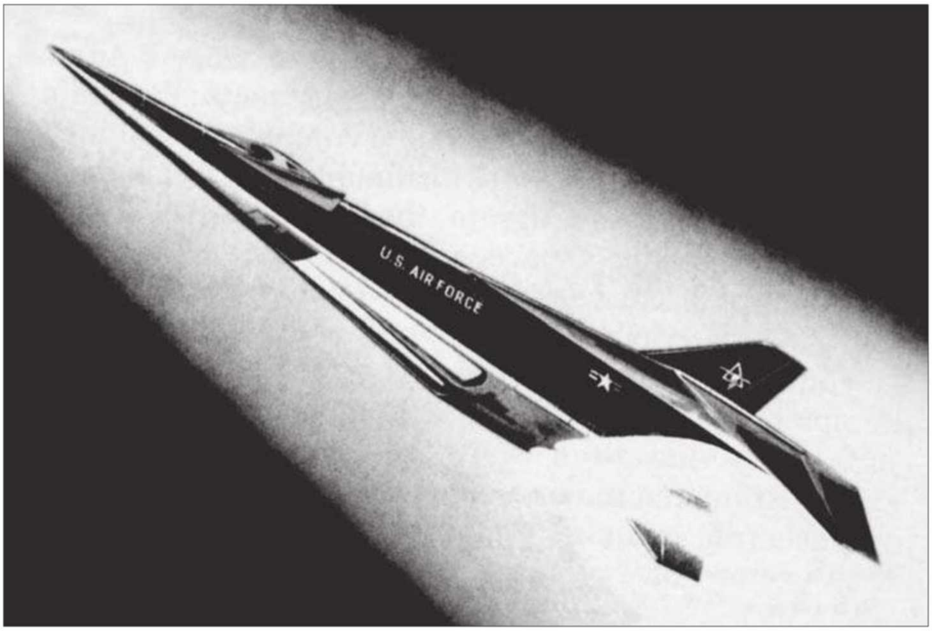
Top right: **X-15A-2 is released from the carrier aircraft.** NASA

Centre: **One of many proposals for an advanced delta winged X-15-3.** USAF

Bottom: **NASA concept for the X-15-3. A number of follow-on proposals were considered with plans for rocket and B-70 launches.** NASA



The CL-839-28 was a Lockheed proposal to increase the performance of the North American X-15 with a stretched fuselage and a large delta wing. The aim was to achieve a speed of Mach 8 and this project was called the Manned Hypersonic Cruise Vehicle (MHCV). It would be air-launched from a converted B-52 bomber and further research indicated that Mach 12 might be attainable. Pete Clukey/Lockheed-Martin



A very advanced delta wing concept with small canard fins. The vehicle appears to be designed to operate as a waverider with scramjet propulsion. USAF

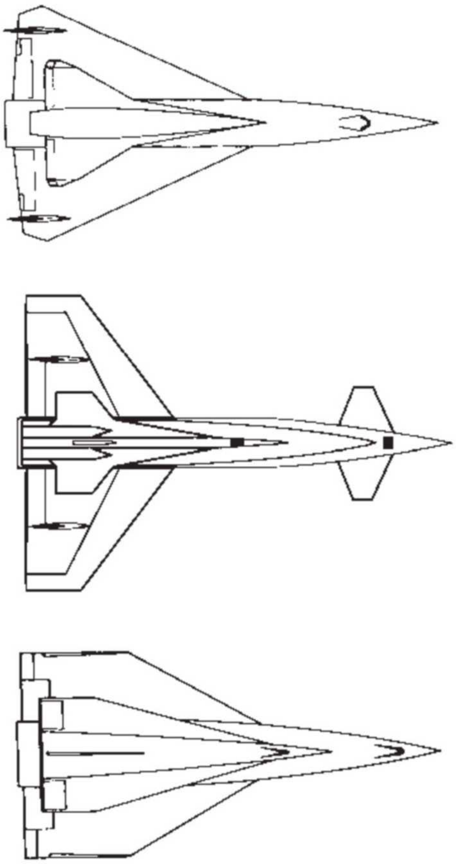
stage, it was planned to build a delta-winged variant with the wing leading edges made in columbium (now known as niobium), an uprated rocket engine and a fuselage section stretched by 12ft 6in (3.81m). It was also considered advantageous to launch this delta X-15 from the back of a North American B-70 Valkyrie bomber at high altitude and supersonic speed. NASA expected to convert the third X-15 into this configuration, but after the aircraft's loss there were insufficient funds to build a delta version from scratch.

Another option, which received serious consideration prior to the Russian launch of Sputnik in 1957, was an orbital vehicle based on the X-15. This expendable lightweight one-man X-15 would be launched using several Navaho boosters plus the aircraft's engine. The astronaut would complete a single orbit and then, on return, would eject and abandon the X-15 over the Gulf of Mexico. A two-seat X-15 was also considered as an orbital vehicle which would have been launched with a Titan booster. Capable of carrying small military payloads, the two-seat X-15 would have used an external fuel tank system and at one point the design was put forward for the Dyna-Soar project. NASA also considered using the X-15 to launch Scout rockets carrying small satellites, but finally rejected the idea as too costly and complicated. Perhaps the most advanced proposal was a delta-winged X-15 vehicle that appears to be a waverider. Powered by two ventral scramjet engines, this design would have utilised delta-shaped canards.

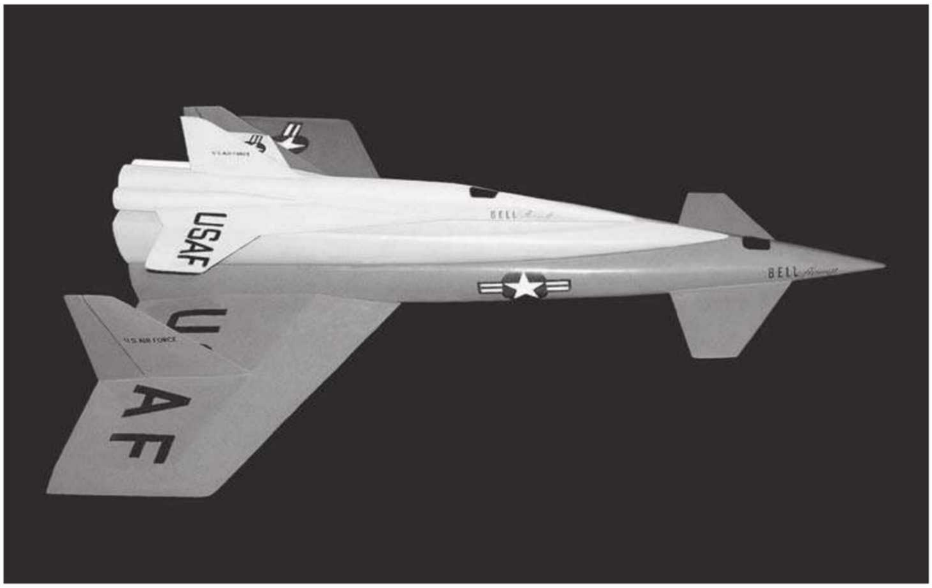
X-15 flights continued until 24th October 1968 when Flight 199 was completed. It had been planned to round off the programme with Flight 200, which would have been flown by USAF Major William J Knight, but, after a series of delays caused by weather, NASA decided to close the project on 20th December. The programme produced invaluable research data on hypersonic flight, it allowed the testing of many new materials and provided a platform for many important small-scale experiments. It's also worth noting that no manned winged vehicle apart from the Space Shuttle had officially exceeded the altitude record set by the X-15 until 2004 when Canadian Arrow's SpaceShipOne made its third flight. The two surviving X-15s are currently on display at US facilities. X-15 66670 can be found at the National Air and Space Museum in Washington, DC, and X-15A-2 is held by the National Museum of the United States Air Force, Wright-Patterson AFB, Ohio.

Advanced Studies at Bell

Major General Walter Dornberger headed the Peenemünde research facility in Germany during World War Two. When hostilities ceased, he was initially held by the Americans and was then taken into custody by the British. This must have been something of a blow to his pride as he had been held as a POW by the French during the First World War. The British wanted to put him on trial for war crimes, but pressure from the Americans



Three of many different proposals for the Bell BoMi produced during the 1950s. Bill Rose



Scale model of a three-stage BoMi proposal with a manned re-usable canard first stage, an expendable second stage and a small one-man spaceplane capable of delivering a nuclear weapon or undertaking a reconnaissance mission. Peter Nash

finally secured his release in 1947. Dornberger immediately travelled to America and worked for the USAF as a consultant until 1950, when he joined the Bell Aircraft Corporation. Initially Dornberger was involved in developing the ASM-A-2 Rascal standoff missile for the USAF. He was joined at Bell by his associate Dr Krafft Ehricke (1917-1984) who was a rocket propulsion specialist. Ehricke had studied under Geiger and Heisenberg at the Berlin Technical University and, like many other Peenemünde scientists, was recruited under Operation *Paperclip* to spend several years in US Government service. Dornberger and Ehricke began working together on long-range rocket-bomber designs for the USAF under the direction of Robert J Woods. Officially called Project MX-2276, the studies became known within Bell as BoMi for 'Bomber Missile' and from the outset this programme was classified as top secret.

If the project proved feasible, it had the potential to leapfrog an entire generation of supersonic jet bombers. BoMi might allow the unstoppable delivery of a nuclear weapon to an enemy target at the speed of a missile, while long-range reconnaissance missions could be flown at altitudes far above the capability of any anticipated air defence system. Their study began with Eugen Sänger's research, but it appears that the idea of sled launching was never considered viable and a fully re-usable vertically launched system was always the preferred choice. They hoped to use the skip-glide principle and it was Dornberger's suggestion that they try to recruit the Sängers to work on the project. But when an approach was finally made in 1952, the Sängers turned it down, preferring to continue living in Paris.

The initial BoMi designs were based on the Sänger-Bredt Silbervogel research documentation, but wind tunnel testing of models and mathematical studies began to evolve in a different direction. The first proposal was for a rocket vehicle with large wings fitted with stabilisers and carrying a smaller second stage, which was a winged rocket vehicle fitted with a single tailfin.

As development progressed, a delta wing shape was chosen as the best option for both manned stages and the tailfin fitted to the second stage was removed and replaced with wingtip control surfaces. By spring 1952 this had become a highly detailed study for a two-stage high-altitude rocketplane and it was designed to deliver a single atomic weapon over an intercontinental distance. The delta winged first stage would carry a crew of two. It would be 120ft (36.5m) in length with a wingspan of 60ft (18m). Power came from five liquid fuel rocket engines which would burn for two minutes before separation took place and the vehicle would finally return to base to make a runway landing.

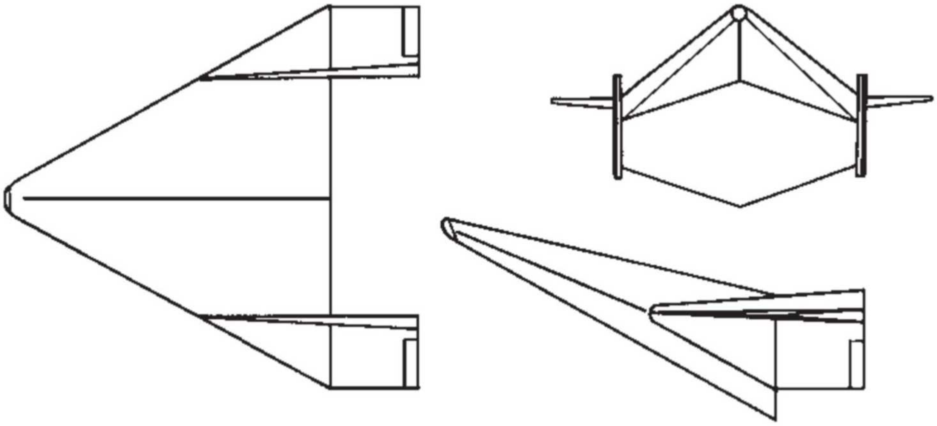
The one-man second stage would utilise three liquid fuel rocket engines that were identical in design to those used by the launch stage. It was proposed that the engines in both stages would run on a mixture of nitric acid and un-dimethylhydrazine (UDMH) and the formulation of this (very unpleasant) storable rocket fuel was regarded as highly classified at that time. The delta-winged second stage resembled a scaled down first stage and had a length of 60ft (18m) and a wingspan of 36ft (11m). In its initial form the vehicle would climb to an altitude of 100,000ft (30,500m) and reach a cruise speed of Mach 4. The maximum payload would be 4,000 lb (1,800kg), which was considered sufficient to allow the carriage of an early atomic bomb. Maximum range was set at 3,750 miles (6,035km) and gross launch weight was estimated to be 793,664 lb (360,000kg). With the initial study completed Ehricke moved to Convair, although he retained close links with Dornberger and continued to advise on aspects of the project.

By summer 1952 Bell had put some initial proposals to the USAF's Wright Air Development Center, who were sufficiently impressed to provide $398,459 for further studies lasting until mid-1953. However, it was now decided that BoMi should be studied in two different versions. The first would be an improved sub-orbital system employing a re-designed upper stage airframe mostly built from aluminium, but with titanium used in thermally critical areas such as the wing's leading edges. Operational requirements for this revised system appear to be fairly similar to the original specification. The second version was expected to have orbital capability. Most of the upper stage would be built from titanium and it was hoped to use a spray-on graphite-epoxy material as an ablative heat shield for vulnerable areas of the fuselage. The orbital design would be somewhat larger with the launch stage having a length of 144ft (44m), while the upper stage had a length of 75ft (22.8m). The three liquid-fuelled engines (using liquid oxygen/hydrogen) would be uprated and the craft would use an unusual linear bomb bay and carry two nuclear weapons that were to be ejected rearwards. This ejection system was under development by North American Aviation's Columbus, Ohio Division for a proposed Mach 2 naval attack-bomber that eventually became the A3J (A-5) Vigilante.

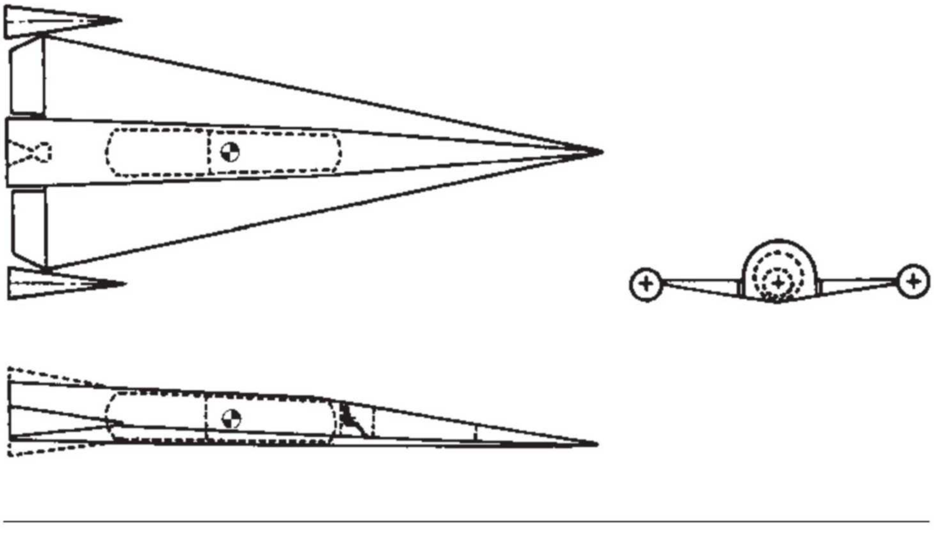
A further version of the BoMi design would use a stretched carrier stage fitted with canard foreplanes and equipped with eight rocket engines. This vehicle bears some resemblance to a large recoverable booster proposed by North American in 1949 for a two-stage Navaho missile system. It would carry an eight engine second stage rocket (probably expendable) and a three-engined spaceplane. In April 1953 the USAF reviewed the study, but regarded the lift/drag estimates as unrealistic and had serious concerns about certain thermal issues. It was felt that the design could be built but it would be restricted to a research vehicle with the potential for reconnaissance missions. The USAF continued to study Bell's proposals for several months and finally made a number of recommendations and requests, issuing a further study contract for Project MX-2276 on 1st April 1954 and funding it with $220,000. The development of BoMi continued in a very haphazard manner with a stream of minor revisions and changes to the specification being issued by the USAF.

Then the Wright Air Development Center issued System Requirement SR-12 on 4th January 1955 for a high-speed reconnaissance vehicle having the ability to operate at 100,000ft (30km) and a range of 3,100 miles (5,000km). This was followed by General Operations Requirement GOR-12 issued on 12th May which was a slightly updated version of SR-12 that called for an operational system by late 1959. The next set of design alterations followed a classified NACA report which found that the skip-glide technique was unworkable with prevailing technologies and boost-glide was the better option. Subsequently, the USAF provided funding to expand and extend the BoMi study under Weapon System WS-118P in September 1955. By the end of 1955 Bell was proposing a manned Mach 15 vehicle boosted to 165,000ft (50km) by a two-stage rocket. Initially, the vehicle would have a range of 5,000 miles (8,046km) but this could be extended as development progressed. In the second phase BoMi would have a 10,000 miles (16,093km) range, and finally it would be orbital.

At the beginning of March 1956 the USAF produced proposals to build an experimental vehicle called the Hypersonic Weapon And R&D System (HYWARDS). This was considered necessary to support the BoMi project and plans for HYWARDS were formalised under SR-131 on 6th November 1956. HYWARDS (designated System 455L) would be a small delta-shaped flat-bottom spaceplane capable of reaching speeds of Mach 15 and was considered in manned and unmanned configurations. The vehicle would be powered by one of several possible liquid-fuel rocket engines in the 35,000 to 57,000 lb (155 to 253kN) thrust class. Initially, HYWARDS would be air launched from a modified B-52 bomber but subsequent tests would take place at Cape Canaveral using converted ICBMs which would lift the vehicle to an altitude of 350,000ft (106,700m). HYWARDS was also seen as the next step forward from the hypersonic North American X-15, which was



This is one of several proposals for the HYWARDS studies secretly undertaken by NACA for the USAF in 1957. The HYWARDS group, based at Langley and headed by John V Becker, believed that a small flat bottom delta was the ideal shape for a research vehicle capable of Mach 15. USAF



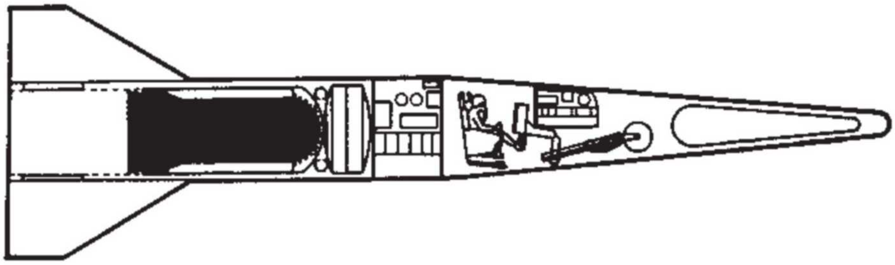
As part of the classified HYWARDS studies, NACA Ames produced this 1957 proposal known as Configuration A for a Mach 10 demonstrator with a 75° delta. A full size 75ft 6in (23m) long rocket powered one-man prototype was planned but never built. USAF then in development. With the X-15 having a design speed of about Mach 7, HYWARDS would represent a major step forward in manned research vehicles.

Two different studies for HYWARDS were undertaken by NACA. The first team was based at NACA Langley and headed by John V Becker (who was also involved with development of the X-15). The second study took place at NACA Ames under the direction of Harvey Allen and Alfred Eggers. They produced a lower performance vehicle with the emphasis placed on lift/drag performance, but finally accepted that the Langley proposal was superior with its higher performance and less demanding cooling requirements. HYWARDS was never built but a great deal of useful aerodynamic research was completed and this would be amalgamated into the ongoing classified rocket-bomber project, which was still in development at Bell.

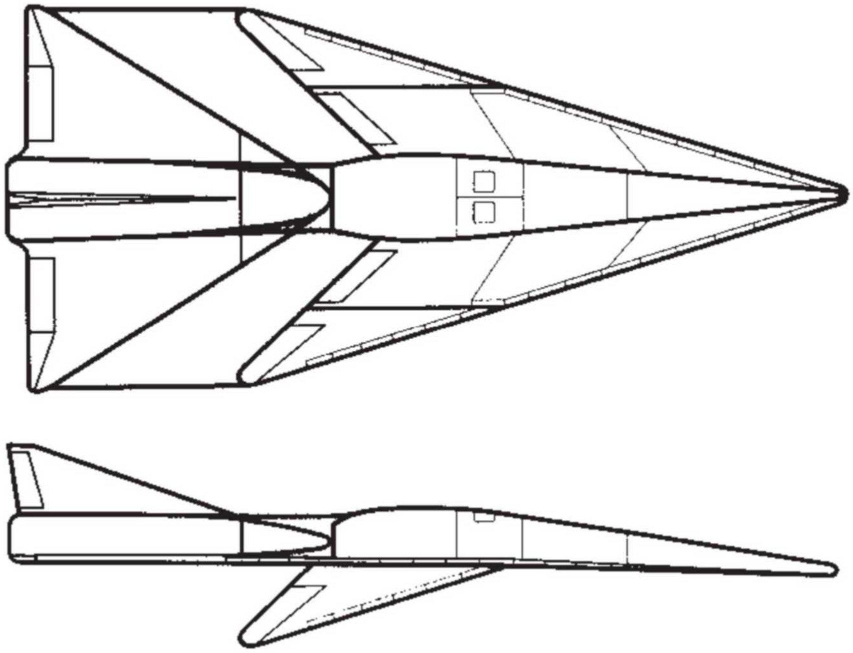
This programme was still being referred to as the BoMi Project by Bell staff, but now carried the official USAF title WS-459L Brass Bell. On 20th March 1956 the USAF provided Bell with $746,000 to extend this study contract and placed NACA in charge of reviewing this particular project (and related hypersonic studies being undertaken at Boeing). BoMi had evolved considerably and now used an expendable launch stage derived from an Atlas missile. This would boost the upper manned vehicle to Mach 16 at a height of 165,000ft (50,300m) and provide a range of 11,500 miles (18,500km). In late 1955 the USAF had also initiated preliminary studies of hypersonic weapons systems with six other defence contractors and the proposals put forward by three of these companies were selected for further development. On 12th June 1956 the USAF issued SR-126 for studies into a vehicle called RoBo (Rocket-Bomber) to Convair, Douglas and North American Aviation, which totalled $860,000. This would primarily be a high performance bomber but it would also have a secondary reconnaissance role. One year later the USAF's RoBo Evaluation Committee met to review progress. Bell remained at the forefront of hypersonic research and Dornberger presented Brass Bell to the USAF as the leading design for the RoBo programme.

Brass Bell was a very sophisticated concept with some fuselage sections built from an advanced aluminium alloy honeycomb covered by a layer of micro-quartz fibre and Inconel-X nickel alloy sheets for the outer skin. Water was used as a coolant for this structure while the leading edges of the wings would be cooled with liquid sodium. Within the spacecraft's total mass of 11 tons (10 tonnes) the payload capacity was set at 1.4 tons (1.27 tonnes). This new three-stage system looked very different to the original BoMi concept, but many features were retained such as the linear ejection system for nuclear weapons and tricycle undercarriage for horizontal runway landings. Forward visibility was restricted to the use of a periscope and some schematics suggest that Brass Bell was configured for an optional second crew member. In its fully developed form Brass Bell would launch vertically and use expendable boosters, which reduced the lift-off weight to 336 tons (305 tonnes) (that is, the total weight with boosters, upper stage and the like). The two first stage boosters were attached to either side of the broadly similar second stage and all three were propelled by fluorine-ammonia-fuelled rockets. Bell continued to lead the RoBo programme but was closely trailed by Douglas who submitted a design with company reference Model 1377, which was also a three-stage concept.

In third place came Boeing and Convair, followed by Republic and Lockheed. The USAF then decided that the way forward was to amalgamate all the existing research work into one new programme and by autumn 1957, Brass Bell, HYWARDS and RoBo had become the System 464L Dyna-Soar project. One other development of the original military system appeared in 1957 when Dornberger and Ehricke proposed the construction of a passenger-carrying rocket transporter. The USAF had agreed to declassify some parts of the early BoMi project and this civil concept



Cross section of Bell's proposal for the RoBo spaceplane known as the SR-126. Bell Aircraft



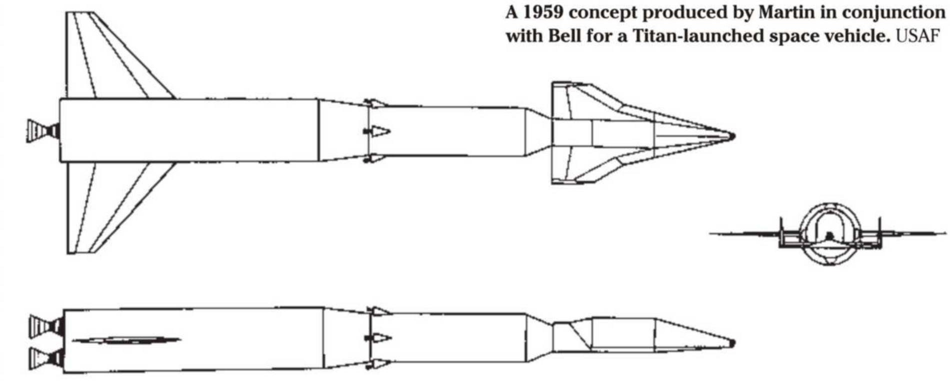
A 1957 design for RoBo produced by Convair's Fort Worth Division. The one-man RoBo vehicle would be mounted ahead of a large winged nuclear missile and an adapter section. After releasing the missile on approach to the target area, the RoBo spaceplane would continue to its landing site. After re-entry the wingtips would fold down to provide improved control. Convair was based on an early BoMi design, making a vertical lift-off and using comparable propulsive technology. Notable differences from the initial military ideas were the flatter underside of the launch vehicle and a single tailfin on the upper stage. This would make a 3,000-mile (4,828km) journey at an altitude of 150,000ft (46,000m) that lasted seventy-five minutes; the vehicle would carry twenty passengers. Somewhat optimistically it was suggested that fares would be no more than double the cost for a normal flight.

Bell approached several US airlines with proposals for a transporter based on BoMi which generated considerable interest, but there were no takers for such a risky and potentially expensive proposition. Bell continued to pursue the idea of a high-speed transport vehicle and in 1960 produced designs for a large delta-winged aircraft which would be powered by six turbo-ramjet engines and could operate from normal runways. Capable of Mach 5 cruise at 120,000ft (37,575m) it was expected to become operational in the early 1980s. The vehicle could also be used as the launcher for a smaller rocket-boosted spaceplane. Bell was unable to generate any civil or military interest in this proposal and it progressed no further.

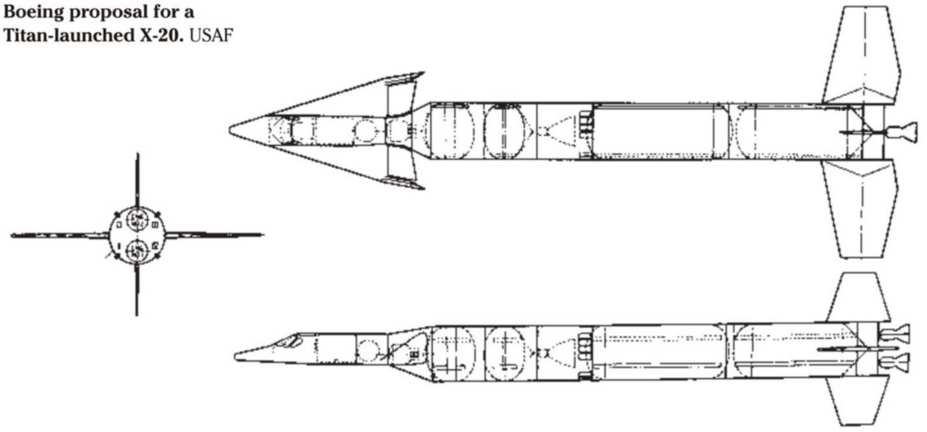
Boeing X-20 Dyna-Soar

The Boeing X-20 Dyna-Soar (Dynamic Soaring) spaceplane was a direct descendant of Eugen Sänger's Silbervogel design but, unlike the original concept, the first X-20 was only weeks away from the start of assembly and less than a year from the first scheduled test flight when the project was cancelled. This was primarily a military space vehicle designed for offensive and reconnaissance operations, but it had considerable civil potential which could have altered the course of America's manned programme in a more positive direction. Following the amalgamation of previous (BoMi/RoBo) spaceplane projects into the new Dyna-Soar programme, a preference was expressed by the USAF for proposals submitted by Bell and Martin together and by Boeing. (Martin's Titan missile was chosen by Bell to launch its Dyna-Soar submission.) However, the Boeing design was considered more technically challenging in the area of cooling.

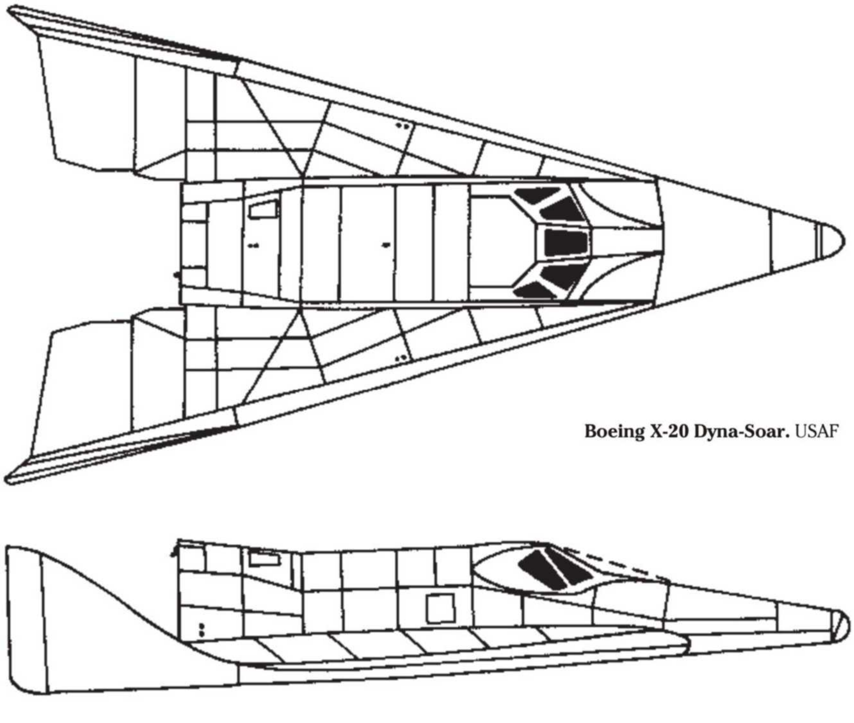
A further $9 million was issued to both organisations for additional studies and by 1959 Boeing's design had altered considerably and now looked much more like the Bell-Martin spaceplane. Much of the research that made the new vehicle possible had been undertaken by Bell, but the contract finally went to Boeing. This came as quite a shock to



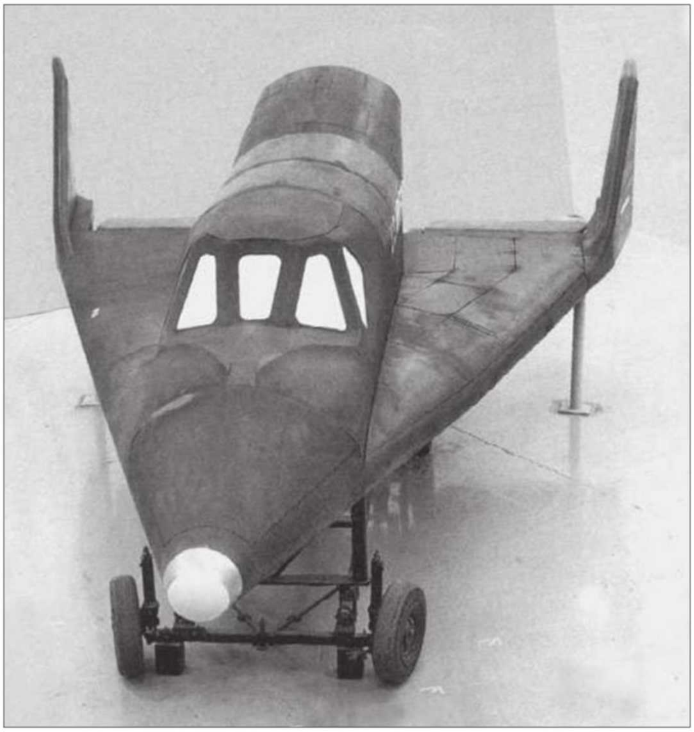
A 1959 concept produced by Martin in conjunction with Bell for a Titan-launched space vehicle. USAF



Boeing proposal for a Titan-launched X-20. USAF



Boeing X-20 Dyna-Soar. USAF

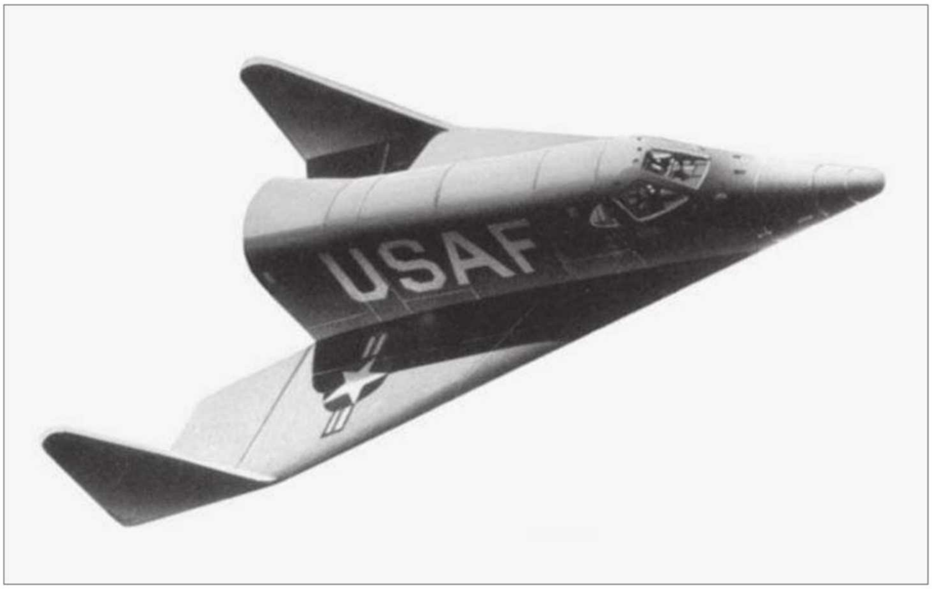


Bell, who had established itself as the country's leading designer of advanced aerospace vehicles. The decision was later seen as politically motivated to favour Boeing who had recently lost out in the Mach 3 B-70 bomber competition, despite being the USAF's premier builder of bombers up that point.

On the 9th November 1959 the USAF formally awarded the WS-464L Dyna-Soar contract (AF33(600)-39831) to Boeing, and this was immediately followed by the first of many development revisions. The programme took the form of a three-phase plan which specified sub-orbital testing, orbital trials and completion as an operational weapons system. In April 1960 seven astronauts were chosen to fly the Dyna-Soar and this group included Neil Armstrong (although he left the programme in 1962).

However, the method of launching Dyna-Soar remained problematic with suggestions for various Titan rocket configurations, a modified Saturn 1, a high altitude launch with a booster stage from a supersonic B-70, or a large high-performance delta-winged ramjet vehicle proposed by Bell. The final preference was for a Titan launcher based on the original ICBM but with the rocket's performance significantly uprated. Titan was developed in the late 1950s for the USAF by the Glenn L Martin Company and used storable (although quite dangerous) liquid propellants to accelerate the launch preparations. Titan proved a very reliable launch vehicle and a good choice for this project.

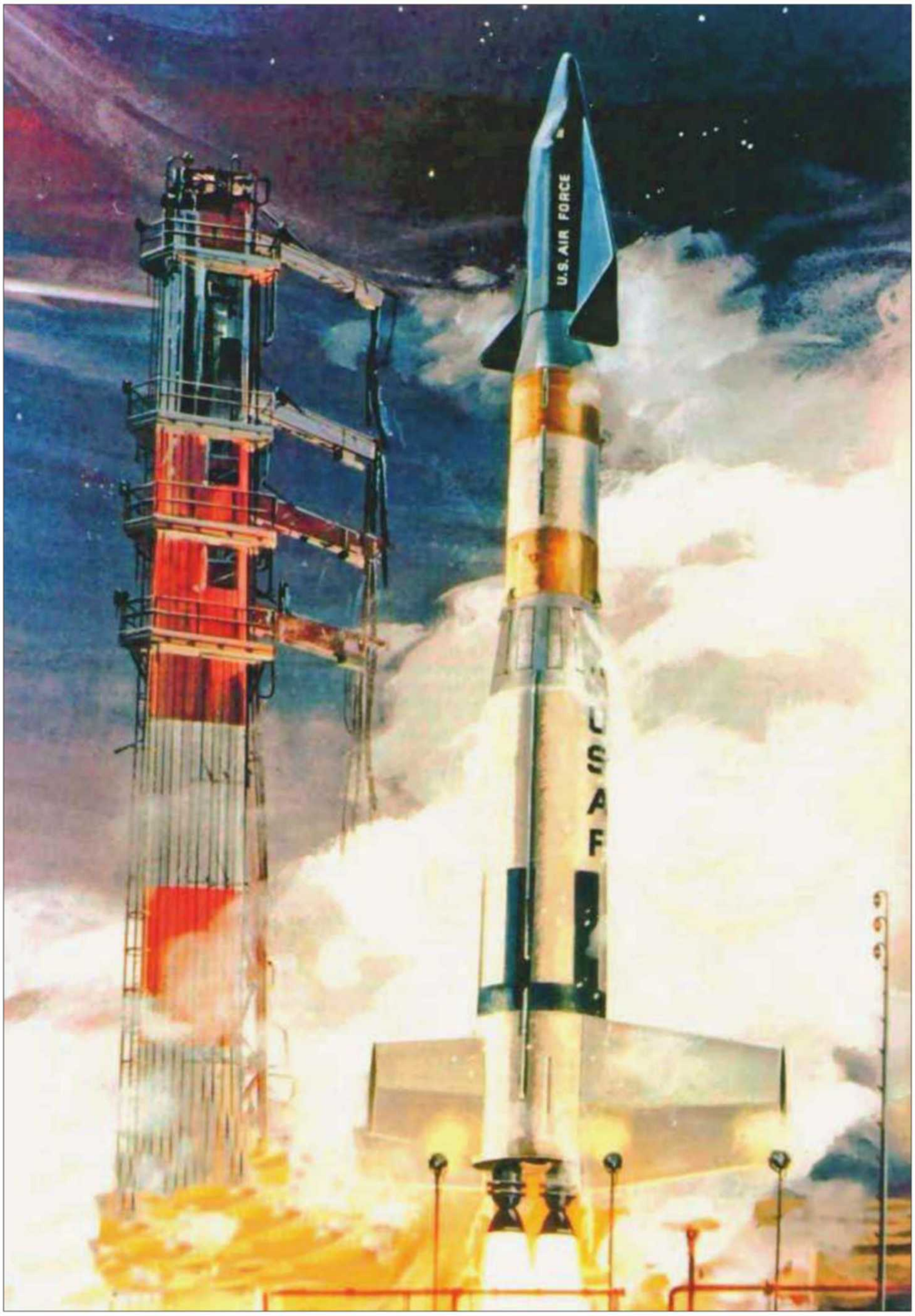
As the Dyna-Soar programme began to gather momentum in early 1960 the degree of interference from different USAF factions increased considerably and launch vehicle requirements were revised on an almost routine basis. There was also high-level political meddling from the Eisenhower and later Kennedy Administrations who could not decide on the right role for the Dyna-Soar; they were also worried about ever increasing development costs. On 11th September 1961 USAF and NASA officials were shown a mock-up of the vehicle at Boeing's Seattle Headquarters. Further improvements had been made to the vehicle's cooling system and there were positive developments with the booster, so the USAF decided to proceed with construction. Boeing was instructed to prepare for production and a contract for ten airframes was issued to the company.



Wind tunnel model of the Boeing X-20 Dyna-Soar (Dynamic Soaring) spaceplane. USAF

Mock-up of the Boeing X-20 Dyna-Soar on its ground handling trolley, with windshield protective cover removed. Boeing

Boeing X-20 Dyna-Soar spaceplane. USAF



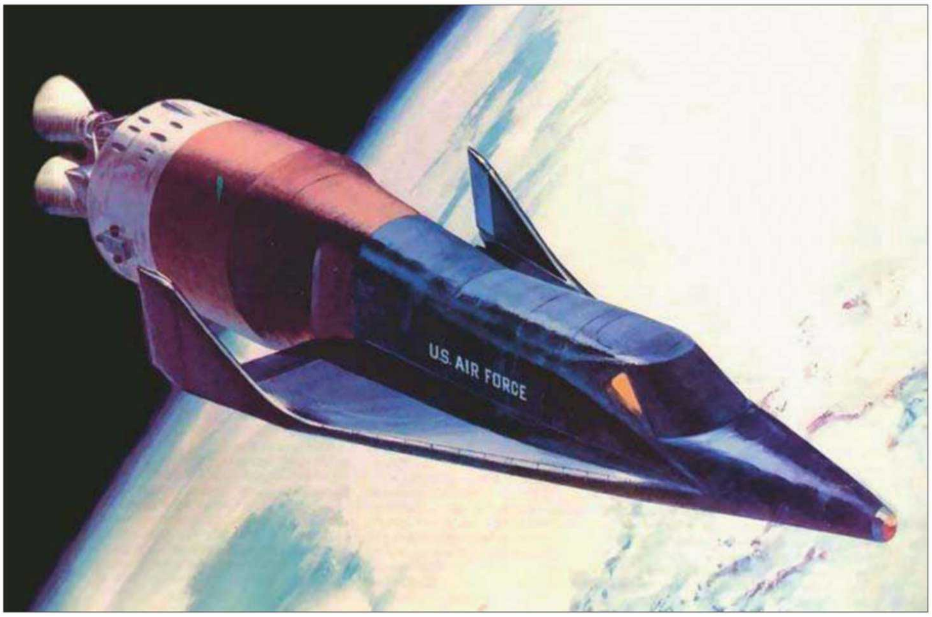
Artwork depicting a dedicated Titan booster lifting the X-20 into space. USAF

With the project now on course the USAF issued serial numbers 612374 to 612383 for these ten Dyna-Soars. The one-man delta-shaped Dyna-Soar was equipped with winglet control surfaces and has often been referred to as a glider because it carried no propulsive system and would make an unpowered return to Earth. That said, Dyna-Soar would have used a detachable liquid-fuelled rocket propulsion module called a transition stage (transtage) and there was also a small solid fuel abort stage for emergencies carried in a unit between the spacecraft and transtage. The initial Dyna-Soar vehicle measured 35ft 4in (10.77m) in length and had a height of 8ft 6in (2.59m) (excluding the landing skids when they were extended). Wingspan was 20ft 10in (6.34m) and wing area 345ft^2 (32m^2). A straight 72.48° wing profile was used and the entire underside of the craft was flat. Maximum take-off or launch weight was 11,387 lb (5,165kg), when empty the craft weighed 10,397 lb (4,716kg) and the payload capacity was 990 lb (450kg).

To deal with high re-entry temperatures Dyna-Soar was mainly constructed from exotic materials, parts of the airframe being fabricated from the superalloy René 41 and columbium. The wing's leading edges were made from molybdenum while zirconium was used for the nose, and the spacecraft was painted in a special black thermal compound. The windshield would be protected with a heat-shield, although the pilot would have visibility through side windows. This would remain in place throughout the mission, only being ejected after re-entry when the spaceplane's speed had dropped to below Mach 6. Although it was obviously desirable to have good forward visibility during landing, Neil Armstrong flew a modified Douglas F4D Skyray fighter with an obscured cockpit canopy to prove that landings could be made with the heat-shield in place if it had failed to separate.

Having reached orbit Dyna-Soar would remain attached to the propulsive transtage, which would allow a significant manoeuvring capability. It was also hoped to utilise a technique called the synergistic orbital manoeuvre which involved dipping into the upper atmosphere to effect an orbital change, with the transtage engine being used to lift the craft back into orbit. The transtage was 15ft (4.6m) long and had a maximum diameter of 10ft (3.1m). Launch mass would be 7,950 lb (3,600kg) and the liquid-fuel engine would use a storable hypergolic mixture of nitrogen tetroxide and Aerozine 50, allowing an Isp of 311 sec and a manoeuvring delta v of 1,475 fps (450m/s). The transtage was also equipped with a reaction control system. The small abort stage was 6ft (1.8m) in length, it had a diameter of 5ft (1.52m) and a mass of 3,000 lb (1,360kg). The solid fuel Thiokol XM-92 motor would produce a thrust of 40,000 lb (178kN) for 13.4 seconds and was primarily intended for launch aborts, but it might also have been used for emergency re-entry procedures and during the air-drop trials.

Titan was selected as the launch vehicle but it was clear from the outset that Titan I did not have sufficient power to lift the Dyna-Soar into orbit. Titan I was soon replaced by Titan II but Titan IIIC was favoured for eventual use – the selection process proved complicated and very bureaucratic. The fully developed Dyna-Soar would climb at a rate of 100,000ft/min (30,500m/min), reaching an orbit provisionally estimated at about 100 miles (160km) and a speed of 17,500mph (28,165km/h). Test flights with the first Dyna-Soar vehicle were originally planned to begin in July 1963, but this date was pushed back by almost a year. The first un-powered air-drops would be made from a modified B-52C



Artwork depicting the Boeing X-20 in orbit, with transition stage attached and windshield protector in place. USAF

bomber operating from Edwards AFB and these would be followed by several launches that would be boosted to supersonic speed by a rocket unit. Various propulsion options were considered, including the solid fuel abort stage, but the preference was for a unit containing a liquid-fuelled XLR11 or XLR-99 rocket. This was expected to provide the air launched Dyna-Soar with an ability to reach Mach 2 at 80,000ft (24,000m). In total, twenty air launches were envisaged before the first sub-orbital flight was made. With constant revisions to the specification it seems unlikely that the planned rocket launches would have taken place on the envisaged dates.

Originally it was hoped to make five unmanned sub-orbital tests, to be followed by a further eleven manned sub-orbital flights to landing sites at the Bahamas and Fortaleza, Brazil. After the mission a modified Lockheed C-130 might have been used to carry the vehicle (under its wing) back to Cape Canaveral. However, the launch schedule was revised in light of booster development and expected to begin with two unmanned launches in January and April 1966, followed by the first manned orbital flight in mid-1966 made by USAF test-pilot James W Wood. Seven further manned orbital missions were planned lasting until early 1968, when Phase One of the Dyna-Soar programme would reach completion.

A single orbit mission would begin at Cape Canaveral's Complex 40. The Titan IIIC booster would lift the Dyna-Soar and transtage to an altitude of 60 miles (98km). Following separation it would climb to an altitude of 90 miles (146km), in the process passing over South Africa. The transtage would then be jettisoned above the Indian Ocean and the long re-entry glide would begin as the Dyna-Soar prepared to land at Edwards AFB, some 107 minutes after launch. The main difference with a multi-orbit mission would be the initial altitude required by the vehicle, set at 114 miles (183km), and the necessity to make a re-entry burn. Because of concerns about overheating tyres housed in the undercarriage bays, it was decided to use landing skids made from Inconel-X and fitted with unusual wire brush contact surfaces made from René 41. Tests on asphalt and concrete proved satisfactory, although the landing sites would have been dry lakebeds near Edwards AFB.

While the orbital flights of Dyna-Soar I were being undertaken, the next phase of the programme would begin at Boeing to produce an operational reconnaissance version known as Dyna-Soar II. Equipped with high-resolution optical and infrared cameras, Dyna-Soar II would also utilise a side-looking radar and 'Ferret' electronic intelligence sensors. It was also recommended that Dyna-Soar II should be equipped with the basic means to deliver nuclear weapons. The USAF anticipated that air-drop tests of Dyna-Soar II would begin in 1966 and rocket launch tests the following year, with operational deployment by 1969. There were concerns that the Mach 3+ Lockheed A-12 would be susceptible to Soviet air defences by this time and Dyna-Soar II was seen as the logical successor to the USAF's supersonic reconnaissance aircraft.

Dyna-Soar III was the next development and this spaceplane would have all the capabilities of Dyna-Soar II, plus the ability to undertake offensive roles against space and ground targets. Testing on Dyna-Soar III would begin in the early 1970s with an initial space launch in 1971. The USAF hoped it would become operational as a weapons system in 1974 at the latest and that Dyna-Soar II would be able to undertake a wide variety of missions.

Orbital reconnaissance using a manned spaceplane was expected to yield superior results to existing satellites, with the possibility of some data being returned to ground stations. However, the quality and security of data transmission was significantly limited and there would still be a reliance on film capsules which would be ejected from the vehicle during longer duration missions. The Dyna-Soar configured for weapons delivery would have the ability to approach a target from any direction, allowing relatively little warning, and it could switch targets or abort the mission which gave the system a considerable advantage over an ICBM. A further proposed development was a larger two-man version called Dyna-MOWS (Manned Orbital Weapons System) with a generally enhanced capability. Another two-man variant was to be designated X-20B and this would be specifically configured for satellite inspection and destruction missions. With an endurance of up to fourteen days, X-20B would have the ability to reach 1,000 mile (1,600km) orbits. Its offensive weapons would be space-to-space missiles and/or a recoilless cannon.

Other proposed tasks for the more advanced Dyna-Soars would be ferry flights to a manned space station or rescue missions, with the internal aft bay being replaced with a cabin containing seating for four passengers. Satellite retrieval was suggested for Dyna-Soar and the idea was resurrected some years later for the Space Shuttle, although the likelihood of an enemy satellite being booby-trapped would have made this a very risky undertaking. The ultimate development of Dyna-Soar was provisionally called X-20X and was a military utility vehicle capable of undertaking almost any anticipated task. Somewhat larger than the early designs, it was hoped that NASA would develop a version of the X-20X for research purposes.

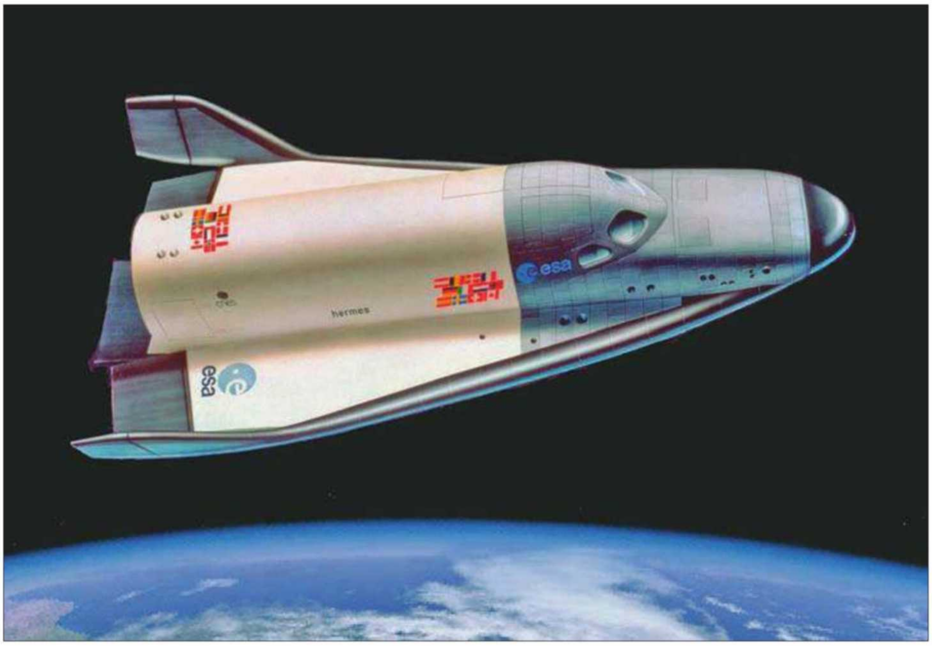
Interestingly, the designation X-20 was only assigned to this project after Secretary of Defence Robert S McNamara wrote to the Secretary of the Air Force in late 1962 suggesting that the project needed re-naming to demonstrate its experimental nature. This was because the White House now believed it was better that the Dyna-Soar was associated with earlier research aircraft like the Bell X-1, and it wanted to steer the public away from the idea of a space bomber. But a lack of focus within the USAF regarding the X-20 continued to have a detrimental effect on the programme, and matters were not helped by the Kennedy Administration's determination to place a heavy emphasis on the peaceful use of space. This meant that NASA received priority over the military for all manned projects.

The USAF was being pushed in the direction of considering NASA's manned ballistic capsules for military roles. Although it had agreed to participate in some aspects of the Gemini and Apollo programmes, the Pentagon intended to retain its spaceplane. This led to the Manned Orbital Laboratory (MOL – below) utilising Gemini and Titan technology, which was proposed as a USAF reconnaissance platform in November 1963. With the X-20 continuing to experience development problems and its cost continually rising, McNamara took the opportunity to recommend MOL as a replacement and he cancelled the X-20 on 10th December 1963. The wisdom of this decision remains debatable and Dyna-Soar was certainly a very advanced piece of engineering, with many systems and innovations that would that would find their way into future aircraft and spacecraft. Consequently, the public was led to believe that the X-20 had been too ambitious, too expensive and the US would be better served with reliable capsules.

Several designs that were similar to Dyna-Soar had been under consideration by the RAE in Britain during the early 1960s and these studies were scrapped when the X-20 programme came to an end. The Soviet Union also attempted to match the capabilities of the X-20 and worked on a series of small spaceplanes. Their development continued over a much longer period and the details are discussed in a later chapter.

Another project inspired by the X-20 started in France during the late 1970s. The French space agency CNES (Centre National d'Études Spatiales) was considering a small manned re-usable spacecraft for future use and requested proposals from Aérospatiale and Dassault-Breguet. These were submitted during April 1985 and, after a detailed review, the CNES decided that both contractors should work on the project with Aérospatiale taking overall responsibility. Aérospatiale would develop the Ariane 5 launcher while Dassault-Breguet worked on the spacecraft called Hermes. Although this spaceplane resembled Dyna-Soar, it was somewhat larger with approximately twice the weight and a crew of three. Fully supported by the French government, CNES presented Hermes to the ESA in 1987 and the project received its approval and financial backing. There were expectations that the first flight would take place in 1995 and Hermes would be used to ferry astronauts to and from the International Space Station. But the need for a European manned space capability became increasingly unclear and there were serious concerns about the spaceplane's rising weight. With the cost of Hermes mounting it met with cancellation in November 1992. An estimated $2 billion had been spent on this project, although Ariane 5 was more successful and entered production in the late 1990s as a satellite launcher.

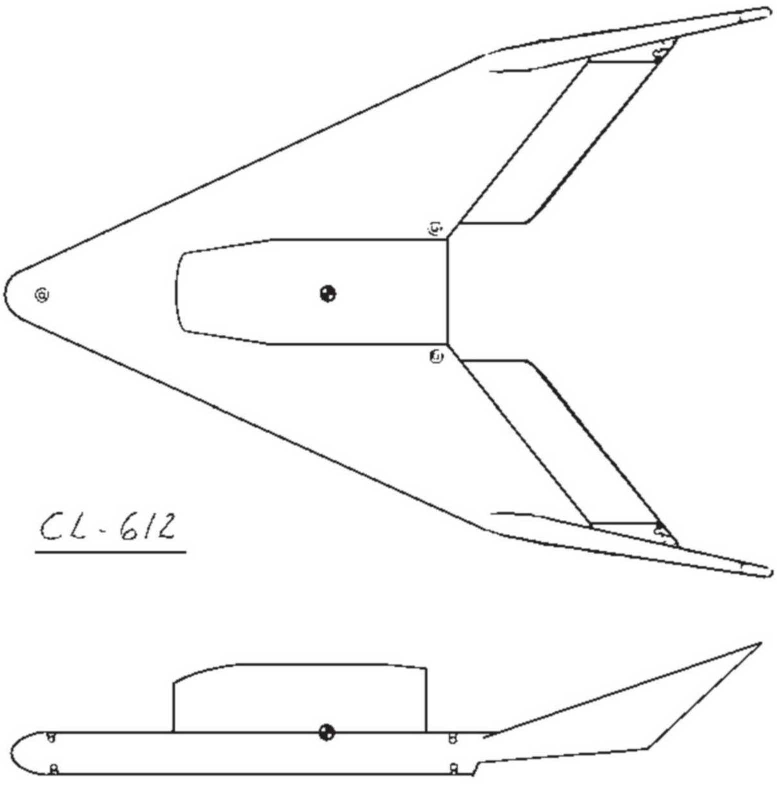
The mock-up of the HL-20 built at NASA Langley. This photograph, taken in 1992, shows the strong Russian influence of this X-20-class design. NASA



Hermes was a proposed three-man (later four to six-man) mini-shuttle with superficial similarities to the X-20. The project was commissioned by the French CNES and later adopted by the European Space Agency, but rising costs eventually led to its cancellation. ESA/Bill Rose

NASA has considered several small spaceplanes since Dyna-Soar and one example was the HL-20 designed by engineers at NASA Langley in the mid-1980s. It was similar in size to the X-20 and would have been launched with a Titan booster. HL-20 was to serve as a backup for the Space Shuttle and as a Crew Emergency Return Vehicle (CERV) for the future space station. Proposals for this compact spacecraft stemmed from US lifting body research in the early 1970s and studies of the Russian BOR-4 re-entry vehicle.

Wind tunnel tests were carried out and a full size mock-up was built in association with several defence contractors, but the HL-20 was never commissioned. However, NASA remained interested in the project and in 1997 a significantly improved version called the HL-42 was proposed. This spacecraft was 42% bigger than the HL-20, hence the designation HL-42, although coincidentally the vehicle's length was 42ft (12.8m). HL-42 would have been a very useful backup for the Space Shuttle (especially after the loss of Columbia on 1st February 2003) but it never progressed beyond the mock-up stage. Another American spacecraft based on lifting body research was the X-38 produced by Orbital Sciences. X-38 was designed in 1995 to function as a CERV for the International Space Station (ISS) when NASA decided that the Russian Soyuz craft was inadequate for the station's expected complement of six personnel. It was also offered to ESA as a possible ferry craft to replace Hermes, but the project was cancelled on 29th April 2002 because of rising costs.



Military Uses for NASA Hardware

During the 1950s there was a USAF programme which had the single aim of putting an American into space before the Russians. There had been various proposals for manned spaceflight that dated back to the immediate postwar years, but the first serious USAF study began on 1st March 1956 as Project 7969. Also known as the Manned Ballistic Rocket Research System, this study examined ways to launch a manned capsule into orbit and safely recover it. Initial ideas seemed viable and several defence contractors were commissioned to work on the programme. Project 7969 would begin with the launch and recovery of small satellites, but would lead to a manned mission by 1960. However, following the Russian success with Sputnik in 1957 more resources were made available for the project, which was now being called 'Man In Space Soonest' or MISS.

The USAF wanted a simple ballistic capsule launched with an adapted Atlas ICBM, but the contractors were soon making alternative proposals that extended from a small spaceplane resembling the BoMi to a lightweight version of the X-15. The studies continued until 29th January 1958 when a review was held at Wright-Patterson AFB with the participation of NACA in a supporting role. Nevertheless, the USAF was set on the idea of a manned ballistic capsule and the outcome of this review was an agreement between USAF General Donald Putt (who headed R&D) and Dr Hugh L Dryden (who was the Director of NACA) to drop the other proposals. Within months the initial selection of test pilots for this project had been completed, but on 1st October 1958 NACA was reformed into the National Aeronautics & Space Administration (NASA) and was given responsibility for the first manned spaceflight. As a consequence MISS passed to the Agency and a few days later it was re-named Project Mercury.

At this time the USAF expected to have an advanced spaceplane at its disposal during the following decade and it seems to have accepted the decision to pass the man-in-space project to NASA fairly gracefully. However, when the X-20 was cancelled in late

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1963 with the stroke a senior official's pen the Service's hopes of securing the high ground took a dramatic fall. The X-20 was destined not to happen, although plans to build more capable military spaceplanes would move into the black domain during the following decades. After the cancellation of Dyna-Soar, the only manned spacecraft available to the USAF were the two-man Gemini and three-man Apollo capsules, which from the outset had been designed for research and exploration purposes and had limited military potential.

The Project Gemini vehicle, initially called Mercury Mark II, was designed by the Canadian engineer Jim Chamberlin (1915-1981) who had been Avro Canada's Technical Design Chief when the highly advanced CF-105 Arrow interceptor was in development. Following the politically motivated cancellation of the Avro Canada CF-105 in 1959, Chamberlin was recruited by NASA and became the senior engineer for Project Mercury. In 1961 he started design work on a more sophisticated two-man capsule to replace Mercury, which was the first US spacecraft to be equipped with an onboard computer, a radar system and ejection seats for a launch abort. The spacecraft was built by McDonnell and, when attached to the

Above left: **Project Mercury capsule number 2 at the Lewis Hangar near Cleveland, Ohio in 1959. Lewis is now the Glenn Research Center.** NASA

Above right: **A Mercury capsule manufactured by McDonnell Aircraft Corporation of St Louis is hoisted into position on a Redstone-Mercury rocket.** NASA

Right: **Astronaut John Glenn climbs into the Mercury Capsule 'Friendship 7' on 20th February 1962 as he prepares for launch. Glenn became the first American to orbit the Earth in a mission lasting just under five hours.** NASA

Opposite page, top: **On 11th December 2007 the Chinese authorities released this photograph which shows a small unmanned test vehicle designated Shenlong (Divine Dragon). Powered by a single engine the prototype is installed beneath a Xian H-6 (Tu-16 copy) bomber (Serial 40672). The date of the picture is unknown but China has been interested in developing a manned military spaceplane for several decades. Shenlong has features that appear to be derived from the X-20 and Orbital Sciences X-34 and this vehicle is almost certainly a demonstrator for a much larger spacecraft.** PLAAF

Opposite page, bottom: **The CL-612 was an early 1960s concept produced for the USAF by Lockheed's Skunk Works. This manned re-entry vehicle was intended to intercept, evaluate and destroy enemy satellites. CL-612 was a brief preliminary study and very little documentation now exists.** Pete Clukey/Lockheed-Martin

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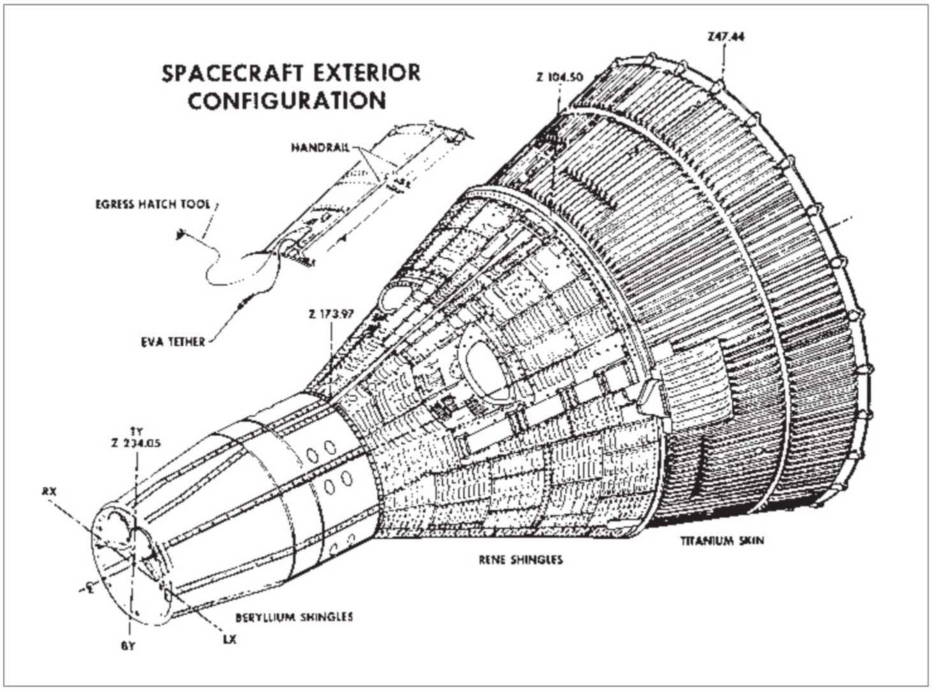
Friendship 7


SPACECRAFT EXTERIOR CONFIGURATION
Z47.44
Z 104.50
HANDRAIL
EGRESS HATCH TOOL
EVA TETHER
Z 173.97
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LX
BERYLLIUM SHINGLES
RENE SHINGLES
TITANIUM SKIN

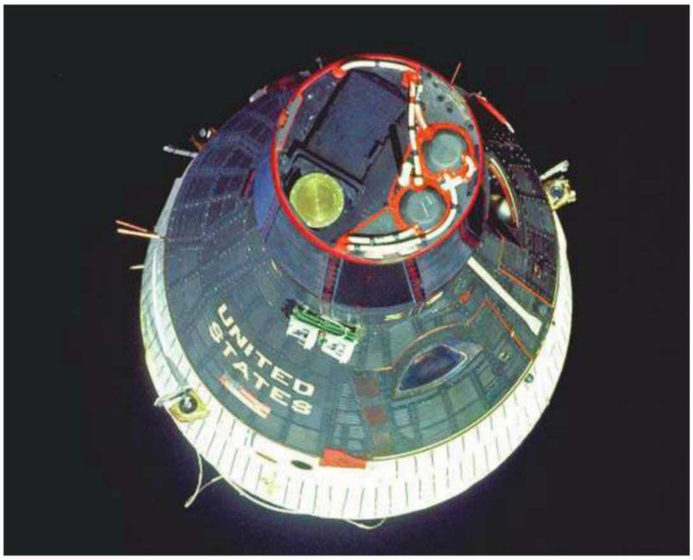
Left: **Exterior detail of the Gemini spacecraft.** McDonnell Aircraft Corporation

Lower left: **The Gemini 7 spacecraft photographed from Gemini 6 during an orbital rendezvous mission.** NASA

Lower right: **The Gemini spacecraft differed considerably from the earlier Mercury capsule in having much of its equipment stored in a module that was attached to the heat shield. This would be jettisoned before re-entry.** NASA

Bottom left: **Mock-up of the proposed Blue Gemini spacecraft in USAF colours. It differed considerably from the NASA vehicle and carried a stowable paraglider intended to allow horizontal landings on a dry lake near Edwards AFB.** USAF

Bottom right: **This Gemini B spacecraft in USAF markings was used for heat testing purposes. Gemini B was not intended to function as a stand-alone spacecraft and would have been used as a crew return vehicle for the MOL. It is currently on display at the National Museum of the USAF.** USAF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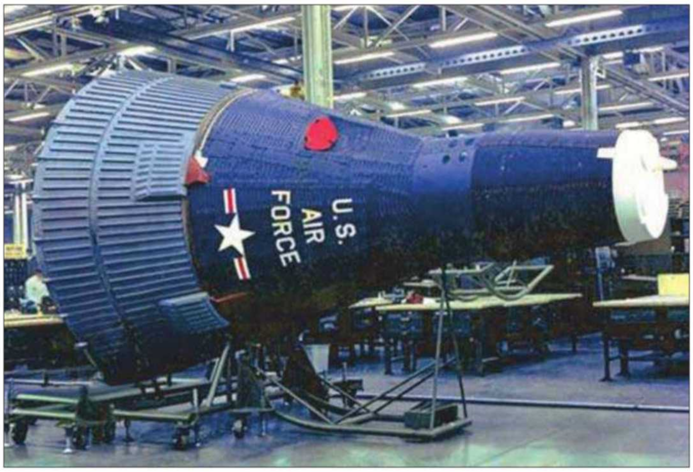
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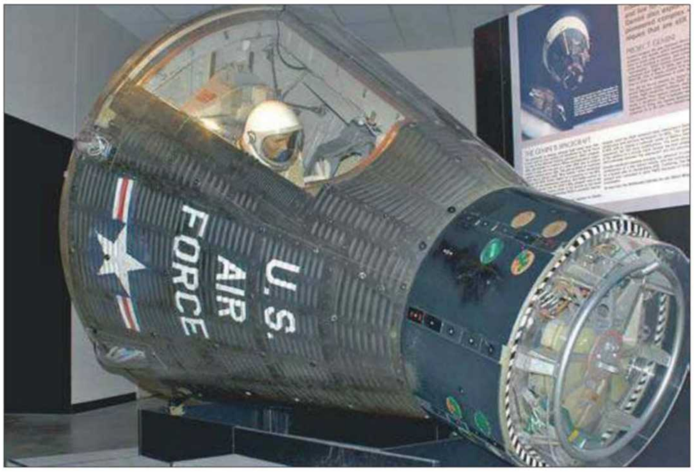

U.S. AIR FORCE

adapter module (containing retro-rocket and equipment sections), it was 18ft 5$\frac{6}{8}$in (5.63m) long with a diameter of 10ft (3.05m). A modified Titan II rocket carried Gemini into orbit and missions could last up to fourteen days. Gemini was significantly more advanced than the basic one-man Mercury and in some respects it was technically superior to the larger Apollo capsule.

In mid-1962 the USAF began to consider using the Gemini spacecraft as a support vehicle for its proposed Manned Orbital Development System (MODS), which was the forerunner of the USAF's MOL reconnaissance platform discussed shortly. The USAF also examined using the Gemini spacecraft alongside Dyna-Soar, but the idea was strongly resisted by the Chief of Staff, General Curtis E LeMay, who correctly predicted that Gemini had the potential to destabilise the Dyna-Soar programme. Nevertheless, despite these concerns the USAF's involvement with Gemini increased and the military programme was now being referred to as Blue Gemini (a name chosen to reflect the USAF's blue uniform). It was proposed that NASA would fund the initial Gemini flights and the USAF would participate in later missions by providing co-pilots. Then the USAF would begin to use its own modified Gemini spacecraft manned by USAF crews. Blue Gemini, also known as Program 287, would differ considerably from the NASA spacecraft and the USAF planned to use a stowable paraglider wing for landing which would replace the parachute system, plus three extendable skids that would allow Blue Gemini to land on a dry lake near Edwards AFB. This had been a feature of the original design, but there were problems with development and the system was dropped in favour of a parachute splashdown at sea.

Six or seven Blue Gemini flights were anticipated with the primary aim of gaining manned experience in the space environment and to test out new techniques and military hardware. Single USAF astronauts would undertake the latter flights. For these missions the co-pilot's ejection seat would be removed and the space would be used to carry extra equipment, such as a ground mapping radar system or an observation telescope. Blue Gemini had very limited potential for military use but was considered worthwhile to test rendezvous techniques with satellites, for inspection and possible disablement. Some reports have suggested that modules were designed that would be attached to a Blue Gemini spacecraft to carry military payloads similar in nature to those proposed for Dyna-Soar. There have also been suggestions that an objective of the Blue Gemini programme was to test the ability to intercept Soviet Vostok (East) spacecraft in fixed orbits with a 65° inclination. It was anticipated that Blue Gemini missions would continue until MOL was ready for use, but these USAF plans never received approval and the Gemini programme remained a NASA undertaking with twelve un-manned and manned Gemini missions being completed between 1964 and 1966. Blue Gemini remained an active programme for about six months but was finally cancelled, although some of the technical features proposed by the USAF were adopted by NASA.

A further USAF development of Gemini was called Gemini B and was designed as a component of the MOL space platform. It differed considerably from other Gemini spacecraft in having a hatch in the heat-shield that allowed entry to the MOL. Gemini B was not configured as a stand-alone spacecraft and only operated as a re-entry vehicle; it would be launched attached to the MOL. Having achieved orbit the two astronauts in Gemini B would move to the MOL. Gemini B would then be shut down and the mission in the small space station would last for up to one month. After that the astronauts would re-enter Gemini B, separate from the MOL and make a return to Earth. Although Gemini B looked superficially the same as the other Gemini vehicles, it featured a different cockpit layout and the ejection seats were modified to make room for the small rear hatch, which had a width of 25in (635mm). The capsule had an overall length of 11ft (3.35m) and a maximum diameter of 7ft 9in (2.36m). This slightly bigger diameter came about because Gemini B was fitted with a more substantial heat shield that permitted higher re-entry speeds when returning from a polar orbit. Gemini B used a different reaction control system and six solid propellant retrofire motors were fitted in place of the previous four. These would be fired to de-orbit the capsule or could be used for a launch abort. Having left the MOL, Gemini B would have a fourteen hour life. It was anticipated that two unmanned test flights without the MOL would be conducted before the first operational mission.

MOL – Manned Orbital Laboratory

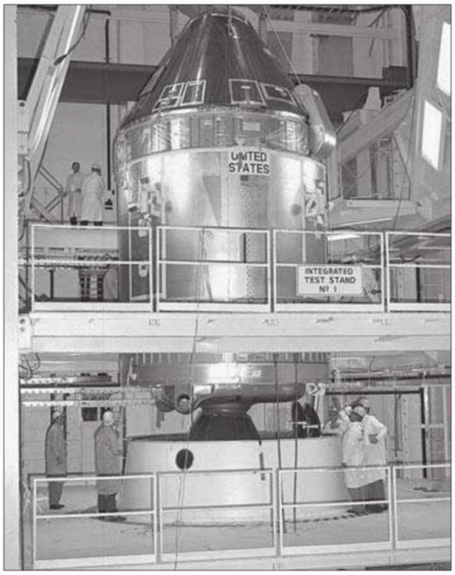
In 1958 the USAF began a modest study called the Military Test Space Station (MTSS), which investigated the idea of building and operating a small manned orbital platform primarily designed for reconnaissance. By the early 1960s the study had evolved into something more sophisticated, which was called the Manned Orbital Development Station (MODS). This would take the form of a cylindrical module launched into orbit by an uprated Titan rocket.

Design work also started on a successor to MODS which had the USAF designation SR-178. Somewhat larger, this orbital station was expected to accommodate three to six astronauts. The launch vehicle remains unknown, although the designers probably had a Saturn class rocket in mind. One ambitious plan called for four of these platforms to be placed in orbit and each would be equipped with optical and infrared cameras, side-looking radar and a full ELINT capability. The Gemini capsule was considered to be the most suitable means to ferry crew to MODS, with the possibility of this spacecraft being replaced by Dyna-Soar when passenger and cargo carrying variants became available. The space station design would eventually become the MOL and the next idea was to integrate a specially adapted version of the Gemini with this smaller expendable design. The capsule would be launched as part of the space station with the sole function of returning the crew to Earth. This was Gemini B.

When the X-20 Dyna-Soar was cancelled on 10th December 1963 it was announced that MOL was under consideration as its successor. As usual with many US military projects, the name was contrived to suggest a peaceful purpose and the description Manned Orbital Laboratory was considered a better choice for public relations than Manned Orbital Spy Platform. The Douglas Aircraft Company in California became the main contractor to build the MOL, which had been assigned the codename AFP-632. The principle surveillance equipment carried by MOL was an optical system developed under the codename Dorian. This was an impressive hand-built instrument based on the Cassegrain system. It used a substantial 72in (1.82m) mirror which had the ability to provide astonishingly detailed images of surface features when atmospheric conditions permitted.

This was the pre-digital era so film used by the telescope's camera would be returned to the ground during the mission in a series of small re-entry capsules. The optical system is thought to have been similar to that used in the Lockheed KH-9 'Big Bird' reconnaissance satellite which operated from 1971 to 1986, although most of the details remain highly classified. Another interesting idea was a very large metallic-coated inflatable parabolic dish that could be used for various intelligence gathering purposes.

Heading the USAF MOL programme was General Bernard A Schriever (1910-2005),



This page:

Left: **The Apollo 11 Capsule and Service Module being attached to the Saturn V adapter during initial assembly tests on 11th April 1969.** NASA

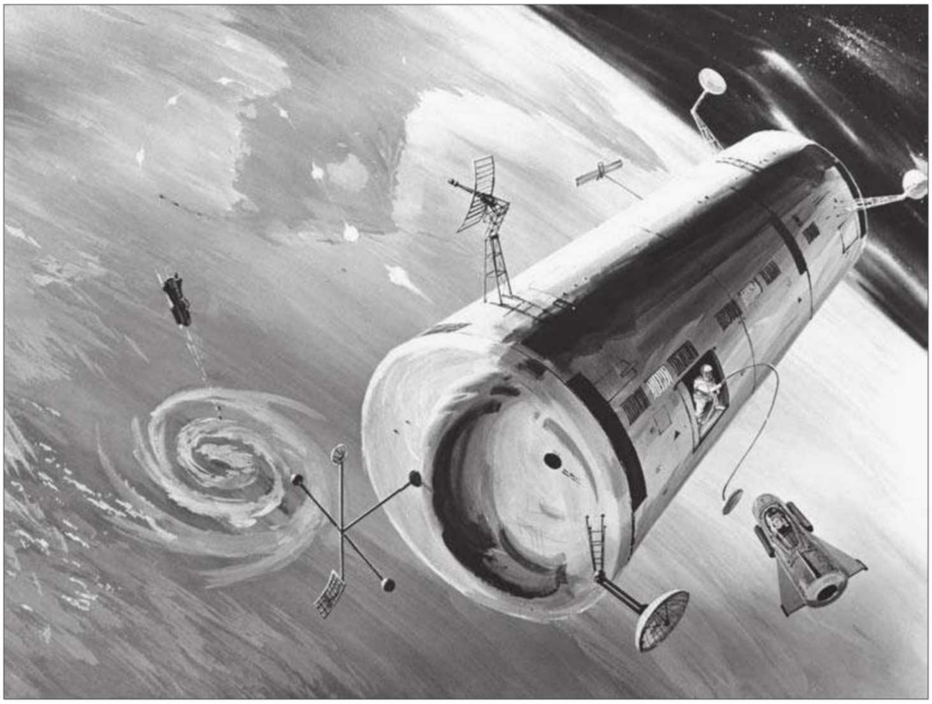
Below: **One of many proposals for an orbital manned space station which followed the USAF's 1958 study called Manned Orbital Development Station (MODS). Plans were eventually scaled down to the relatively modest MOL.** NASA

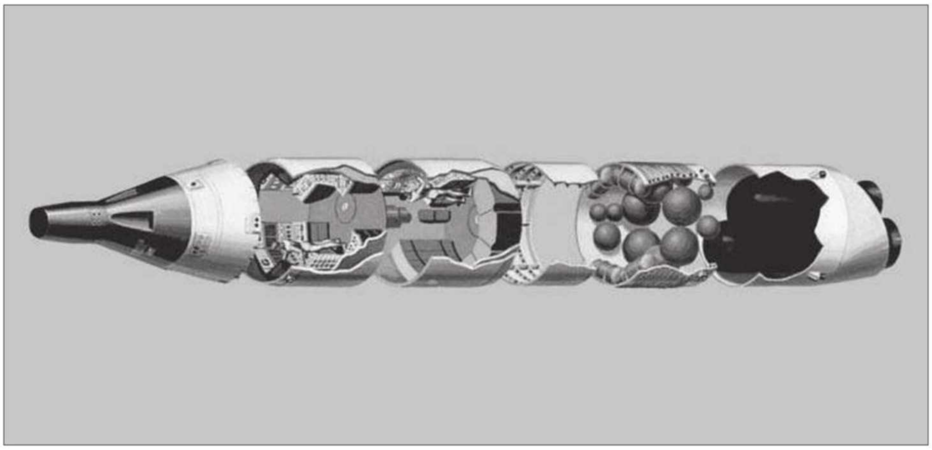
Bottom: **Early section drawing showing components for the MOL.** USAF

Opposite page:

Illustration of a Titan IIIM lifting off with a MOL payload intended for a polar orbit. Boeing

The Gemini B capsule separates from the MOL. USAF



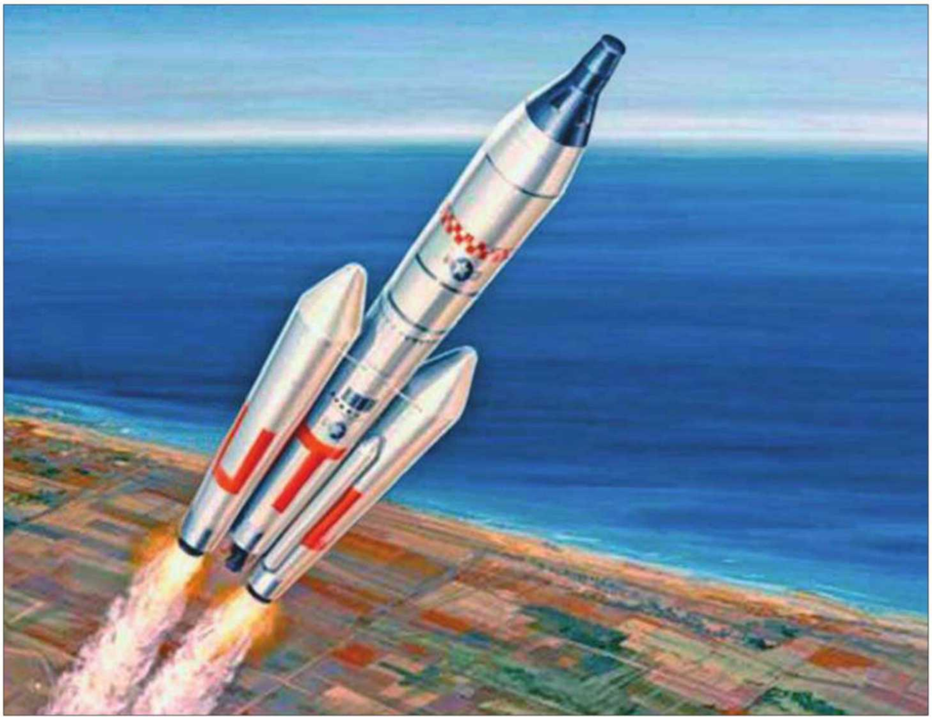


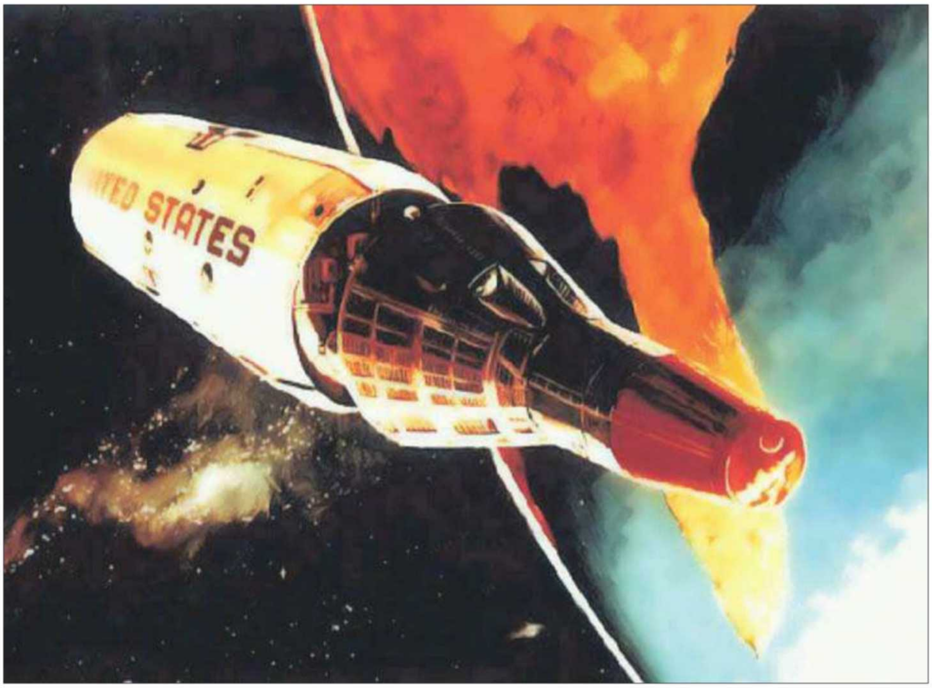
a brilliant organiser who is now best remembered for establishing the ICBM force. His Washington DC office was supported in California by General Russell Berg, who acted as his deputy. This arrangement was deemed necessary as the main contractors for MOL were in California, and so was Vandenberg AFB which would handle most of the launches. The scale of the MOL project generated considerable interest and concern within the Soviet Union and, as a consequence, the Kremlin approved the construction of a broadly similar military space station called Almaz in 1964. Several Almaz vehicles were launched during the 1970s and this programme is discussed in a later chapter. Once operational, MOLs would be launched into orbit using Titan IIIM boosters from either Space Launch Complex 6 (SLC-6) at Vandenberg or Launch Complex 40 (LC-40) at Cape Canaveral, Florida. Having two different launch sites would allow different orbits to be chosen depending on the mission. Landings of returning Gemini B spacecraft would take place near Edwards AFB in California. The MOL was expected to remain operational for one month and, at the end of this period, the two astronauts would then return to Earth. The MOL would be de-orbited over a region like the Pacific Ocean where it would burn up in the atmosphere.

Most of the MOL would be taken up by the Mission Module, which had a length of 36ft (11.24m) and a diameter of 10ft (3.05m). This was divided into two compartments with the forward section having a length of 14ft 6in (4.42m) and the aft section 22ft 4in (6.82m). The overall mass was 31,914 lb (14,476kg) and the MOL would be powered by fuel cells supplemented by solar panels. The upper section had access to the Gemini B's entry hatch via a short tunnel running through an un-pressurised adapter module. The lower compartment was equipped with another tunnel, which might be used at some future stage to accommodate a docked spacecraft or as a means of linking two MOLS together. On 12th March 1966 construction of SLC-6 at Vandenberg was started. This was a substantial undertaking and a major commitment to the MOL project. It was followed on the 3rd November 1966 with the test launch at LC-40 Cape Canaveral of a MOL mock-up using a Titan IIIC rocket. The mock-up was built from a Titan II fuel tank and carried a modified Gemini capsule. The Gemini B made a sub-orbital flight lasting thirty-three minutes and was recovered close to Ascension Island in the South Atlantic by the USS *La Salle*. A hatch had been fitted in the heat shield and no problems were found with the design after recovery. Following release of the Gemini capsule, the MOL mock-up continued into orbit and released three satellites, which helped to offset the launch cost.

A total of seventeen astronauts (all male) had now been selected for MOL missions, although the original dates for planned flights had slipped considerably. Because of budgetary restraints, partly caused by the huge drain on resources generated by the Vietnam War, it was anticipated that the next unmanned test would take place at the end of 1970 followed by another unmanned test approximately eighteen months later. A further five MOL missions were proposed between 1972 and 1975. When NASA's Gemini programme came to an end in 1967, some twenty-two technicians were recruited to work on the MOL programme, although the project began to sink under a growing weight of bureaucracy with many departments failing to communicate with each other. However, one positive change that came about without too much difficulty was the decision to use a mixture of 30% helium and 70% oxygen onboard the MOL. This followed the tragic loss of the Apollo 1 crew on 27th January 1967 in a fire fuelled by the pure oxygen atmosphere.

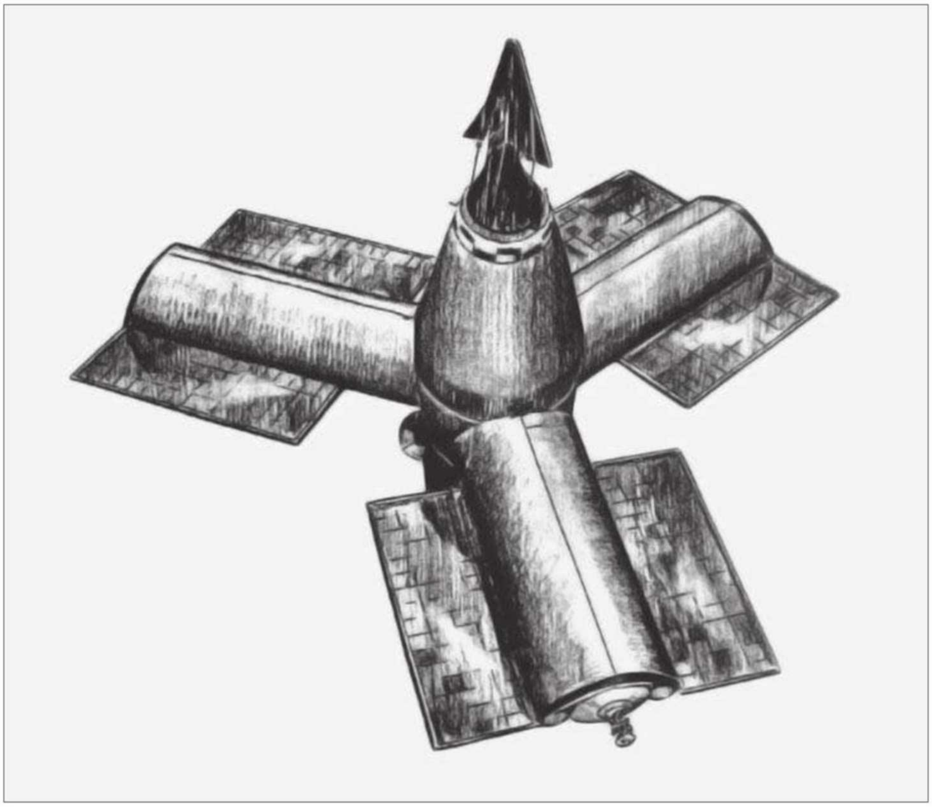
Nevertheless, this was only one of many revisions and the number of engineering changes, often leading to a weight increase, began to cause serious concerns about the lift capability of the Titan IIIC. Consequently, there were plans to upgrade the launch vehicle to a more powerful specification called Titan IIIM. By the end of 1967 funding problems were having a major impact on the project and, within another year, it was apparent that the MOL would need an additional $200 million per annum to continue. It was also becoming clear that, as technology advanced, virtually anything that MOL could achieve was possible using a spy satellite for a good deal less money. Almost $1.5 billion had been spent on MOL when the project was abruptly scrapped on 10th June 1969 by President Richard Nixon. As a direct consequence, large numbers of defence workers lost their jobs and the almost completed SLC-6 complex at Vandenberg AFB was shut down. It would later be revived for Shuttle missions, which themselves were also cancelled, and eventually the facility was used for satellite launches. A few of the astronauts selected for MOL went on to undertake Shuttle missions and some of the technology developed for MOL found uses in later projects. The more advanced Titan IIIM was never built, although certain features were used in later versions of Titan.





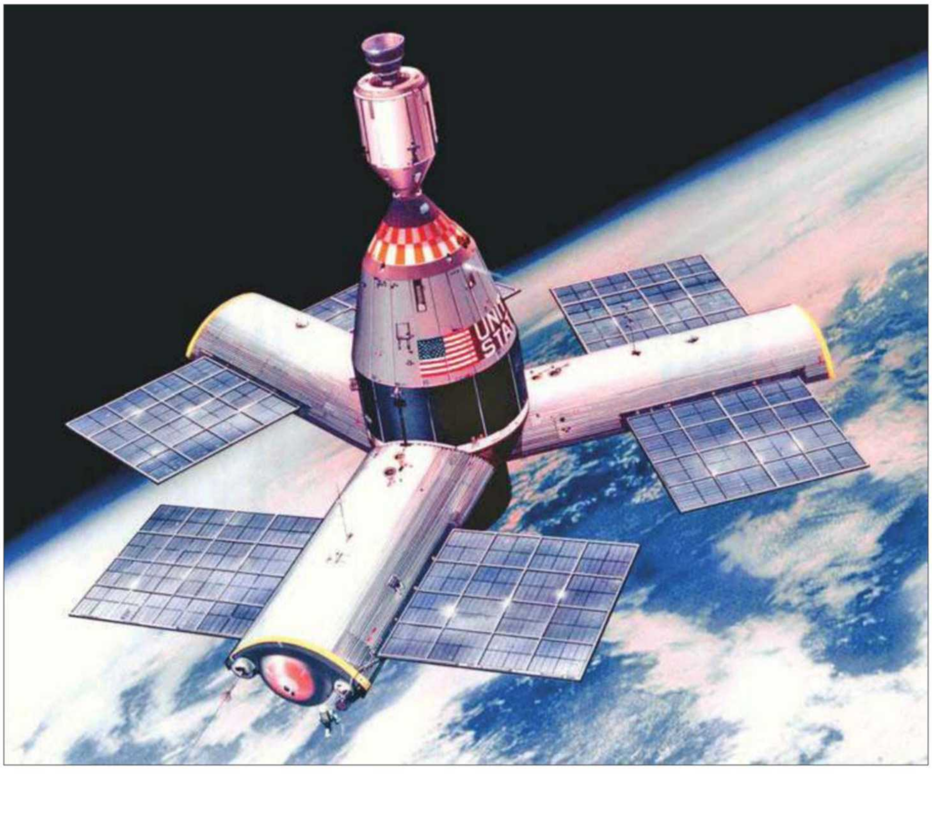
Various upgrades had been considered for the MOL and there were plans to link several together in orbit. Possible configurations were end-to-end or several alongside each other with connecting airlock modules. In this form the space station would be left in orbit for much longer periods and there would be a requirement for extra electrical power that would be met with additional solar panels. As a larger space station system, probably operating at a higher altitude, service flights would be undertaken by Apollo or Big Gemini spacecraft.

Other options may have involved docking with a propulsion stage to allow the MOL to manoeuvre in orbit and undertake satellite inspection. Whether any consideration was ever given to arming MOL remains unknown, although it has been reported that the later Soviet Almaz space stations were equipped with weapons for defensive purposes. Douglas was also working on a NASA study



Large Orbiting Research Laboratory (LORL) was the name used for a number of designs for manned space stations under consideration during the 1960s by NASA and the USAF. This illustration shows one of these concepts, which would have been assembled in orbit from components launch by the Saturn V rocket. USAF

The Large Orbiting Research Laboratory (LORL) illustrated as a civilian facility for NASA in 1960. NASA

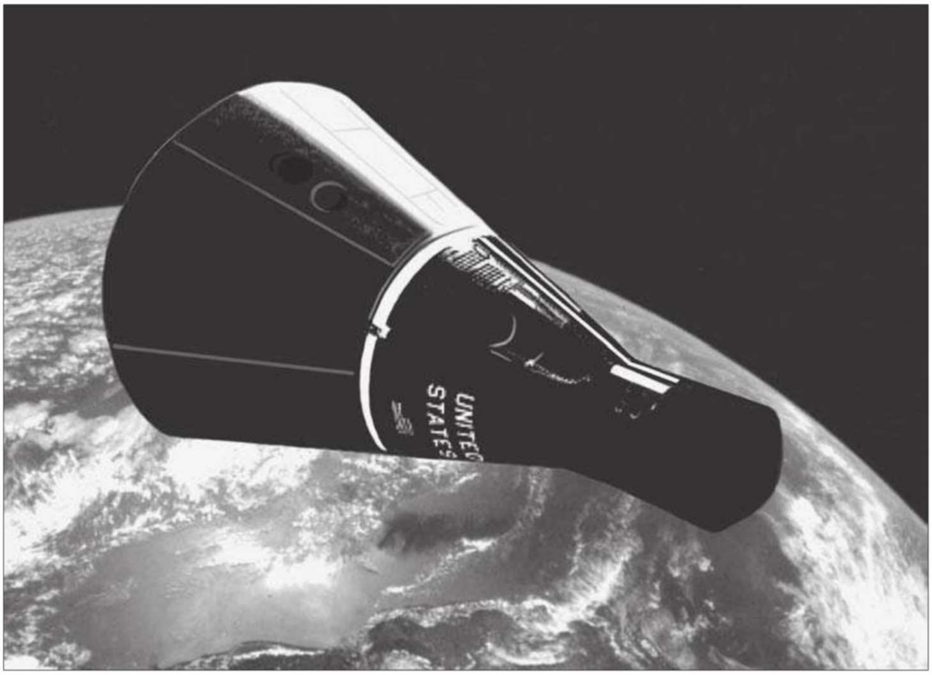


for a larger platform called Manned Orbiting Research Laboratory (MORL) which began in the early 1960s. MORL would be lifted into orbit by a Saturn I-B rocket and would be large enough to accommodate as many as nine astronauts at any given time, with crew quarters and laboratory areas. MORL would have a diameter of 22ft (6.7m), dictated by the launch vehicle, and electrical power would be generated by solar panels. It had a planned weight of 30,000 lb (13,607kg) at launch and would be placed in a higher orbit than MOL, with astronauts remaining onboard for periods of up to six months and possibly undertaking missions lasting a year. Activities would include Earth-mapping, astronomy and onboard science experiments. As the project evolved there were proposals to place MORL in very high Earth orbits or above the Moon to map surface features.

With the ability to use this station as a spacecraft MORL appears to have attracted considerable interest from the USAF, but NASA finally abandoned MORL due to budgetary restraints and there was never any realistic possibility of the USAF switching to this design from MOL. Nevertheless, the USAF remained interested in the idea of operating space stations and studies began during the early 1960s into a very ambitious series of concepts referred to as the Large Orbiting Research Laboratory or LORL. Various designs were considered but the initial proposals had a platform built from cylindrical modules launched by Saturn V rockets and assembled in orbit. The orbital platform would eventually carry a crew of eighteen and be equipped with a pressurised hangar module. Apollo spacecraft would be used for all service flights to the space station until a more advanced transport system became available.

This was followed in 1964 by a USAF commissioned secret study for an even larger rotating version of the space station, which was undertaken by the Lockheed Skunk Works in Los Angeles. Lockheed suggested that that its substantial LORL design could be launched into orbit by 1968 and maintained for five years at a total cost of $2.6 billion dollars. The Lockheed LORL would be launched in sections by Saturn V rockets and, once assembled, could accommodate a crew of twenty-four. Douglas undertook a parallel study for a LORL with broadly similar specifications, but it seems there was never any realistic possibility of LORL being built as a supplement or eventual replacement for MOL.

The ongoing interest in military and civil space stations led McDonnell (then in the



Above: **Designed to outperform the Apollo spacecraft, Big Gemini was a Gemini B capsule with a large additional aft section that was capable of carrying as many as twelve crew members. If a decision had been taken to build one or more LORL space stations, this spacecraft would have been ideal for transporting personnel into orbit.** Bill Rose

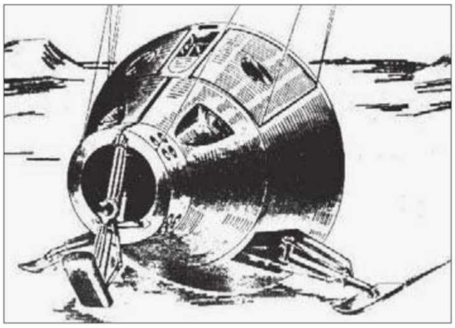
process of becoming McDonnell Douglas) to produce studies for a follow-on spacecraft from Gemini that would out-perform Apollo and could function as a ferry to orbital manned platforms. In 1967 the company unveiled the mock-up of a large re-entry capsule called Big Gemini (later just Big G) to senior USAF and NASA personnel at its St Louis plant. This design was surprisingly simple and, by adding a large aft section to a Gemini B capsule, the engineers had come up with a vehicle that had the same base diameter as Apollo but could carry double the payload. It would be possible to attach Big G to either a USAF Titan or NASA Saturn rocket by means of a different adapter. Big G had an overall length of 37ft 8in (11.47m), a maximum diameter of 14ft (4.26m) and a crew capacity of nine. This could be stretched to twelve, but operations would normally be undertaken with a crew of six. Big G would utilise a retro stage immediately behind the capsule followed by a manoeuvring and cargo module with a docking adapter. An escape tower borrowed from the Apollo system would be fitted for launch emergencies. When configured for USAF use with the Titan IIIM, Big G would have a launch mass of approximately 34,392 lb (15,600kg) and could deliver a crew of nine and 5,500 lb (2,500kg) of supplies to a space station in a 50° inclination orbit at a height of 298 miles (480km). The Saturn-launched NASA version would carry the same number of crew but had the ability to carry larger payloads to similar orbital co-ordinates.

As a newer design Big G would have outperformed Apollo in most respects and could have functioned with Apollo hardware for a range of missions. But its intended purpose was orbital re-supply and crew transfer. Advanced MOL, LORL or NASA alternatives could (each) require as many as six flights per year, perhaps lasting until the 1980s when fully re-usable spaceplanes became operational. After re-entering the atmosphere, Big G would use a parawing (which had now been fully developed by Northrop-Ventura), to make a glide landing at a suitable site, such as one of the dry lakebeds near Edwards AFB. Skids based on earlier Gemini and X-20 designs would be used for the touchdown.

On 21st August 1969 McDonnell Douglas completed its Big G study, but there was never any real prospect of this advanced spacecraft being taken up by the USAF or NASA who both had ambitions far beyond available resources. Gemini has become a largely overlooked spacecraft, but it was well designed and quite versatile considering the limitations of a capsule configuration. One of the little-known Gemini proposals was to land a modified vehicle on the surface of the Moon and it is just conceivable that a Gemini lunar landing could have been achieved a year or so before the historic Apollo mission of 20th July 1969, with a significant cost saving. There was also growing pressure from members of Congress to merge the USAF's MOL programme with NASA's proposed plans to utilise some of the Apollo hardware for other purposes under the Apollo X Program. In 1964 Senator Clinton P Anderson, who was Chairman of the Committee on Aeronautical and Space Sciences, wrote to President Lyndon B Johnson recommending that MOL should be cancelled and a joint national space station built, saving at least one billion dollars over a five-year period. Suggestions soon followed from other quarters that Apollo hardware could easily be adapted for various military uses such as satellite inspection and disablement.

However, despite growing pressure, the USAF and NASA resisted attempts to amalgamate their programmes and managed to hold out against interference for several years. MOL was eventually cancelled and, by that time, it had outgrown its original purpose. Meanwhile the Apollo X led to NASA's Skylab which was placed in orbit on 14th May 1973. After some serious initial problems with solar panel damage, the project proved successful and Skylab remained in orbit and unmanned until the end of the 1970s. It had been hoped to re-use Skylab for Shuttle missions, but the platform required boosting into a higher orbit to save it from breaking up and there were no Shuttles available to undertake a mission before orbital decay led to the space station's destruction.

During the 1960s the USAF and US Navy reviewed the Apollo Moon programme on several occasions for military use. It is known that various adaptations of the Apollo command and service module were considered for space station ferry missions and orbital operations. Northrop-Ventura also studied the possibility of adapting the Apollo capsule for use with a parawing so it could land on skids, which was considered essential by the USAF.



Right: **Big Gemini would have made horizontal landings using a stowable paraglider and skids.** USAF

Perhaps the most interesting development to stem from the Apollo project arose in 1964 when the US Navy (in conjunction with the USAF) began to examine the idea of developing a spacecraft for secret attacks on enemy satellites. This highly classified study considered the possibility of using a variant of the Lunar Module (LM) for Covert Space Denial (CSD) missions. The vehicle would be flown by a two-man crew, have a mass of 33,000 lb (14,968kg) and, with a delta v of 9,800ft/sec (3,000m/s), it would have the ability to undertake substantial orbital manoeuvres. The spacecraft would differ considerably from the Lunar Module. The descent stage would be replaced by an entirely different unit housing larger fuel storage tanks and a rocket engine. The upper engine used for lunar ascent would no longer be required.

Various techniques were considered for making 'silent' approaches to enemy satellites. The LM CSD would be equipped with a single robotic arm which might be used to put masking material over a satellite's communication equipment or place the craft into an uncontrollable spin. Another possibility was to spray black paint over parts of the target vehicle, thereby rendering optics and solar panels useless or perhaps causing the spacecraft to overheat. Attacking manned spacecraft was also studied and a recoilless projectile weapon or small missiles would have been carried. These were operations that might have been undertaken with the Dyna-Soar and so the USAF remained somewhat cool towards the Navy's plans, although exactly how deniable any of these operations would have been remains open to question.

On the 27th January 1967 the United Nations Outer Space Treaty was signed in Washington, London and Moscow. It became effective on 10th October 1967 and an important part of this treaty aimed to stop the introduction of nuclear weapons into space. While it did not bring military operations in space to halt, it had a considerable impact on many politicians who came to regard very expensive military space projects in a less favourable light. The LM CSD project appears to have been largely abandoned by 1967 and, by the end of the 1960s, most of the USAF's manned space projects had fallen by the wayside leaving the Service with little more than ICBMs and reconnaissance satellites. As for building large military space stations, the USAF soon lost interest in this idea. During the planning for the International Space Station in the late 1980s, an Intergovernmental Agreement (IGA) was signed which legally specified its use for peaceful purposes only.

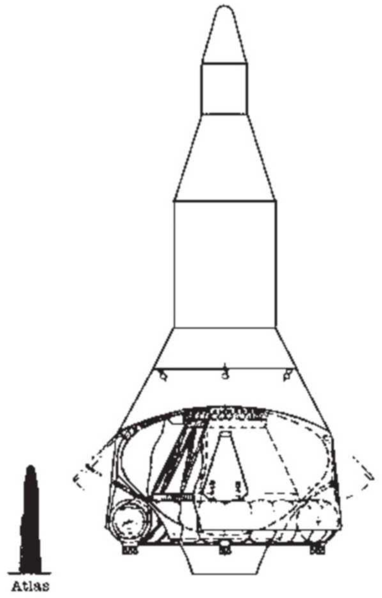
Single Stage To Orbit

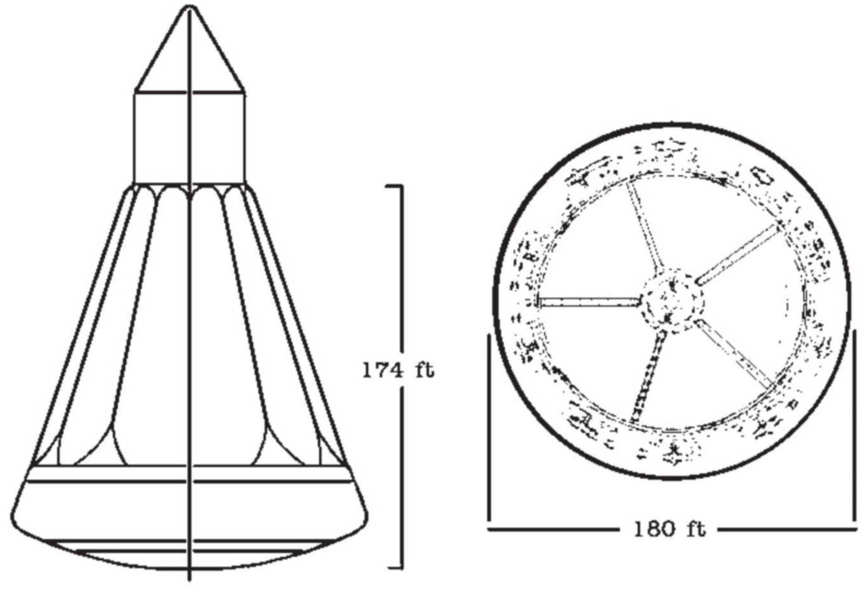
An early proponent of the re-usable single-stage-to-orbit (SSTO) VTOL spacecraft was Philip Bono, who was a talented designer working for the Douglas Space and Missiles Company in California. Soon after moving from Boeing to Douglas in the early 1960s Bono began to develop proposals for a SSTO spacecraft. His newly formed team investigated various concepts that included two nuclear powered designs, although these soon lost favour on safety grounds. However a design called the One-stage Orbital Space Truck (OOST) began to generate considerable interest when it evolved into a re-usable vehicle called ROOST (The 'R' standing for Recoverable). Using conventional liquid-fuelled engines, the largest version of this vehicle was thought capable of delivering a massive payload of 1,000,000 lb (453,592kg) to a 200-mile (323km) orbit. NASA was impressed by these unusual designs but requested studies from several alternative contractors for similarly specified large re-usable SSTO vehicles that could be recovered at sea like ROOST.

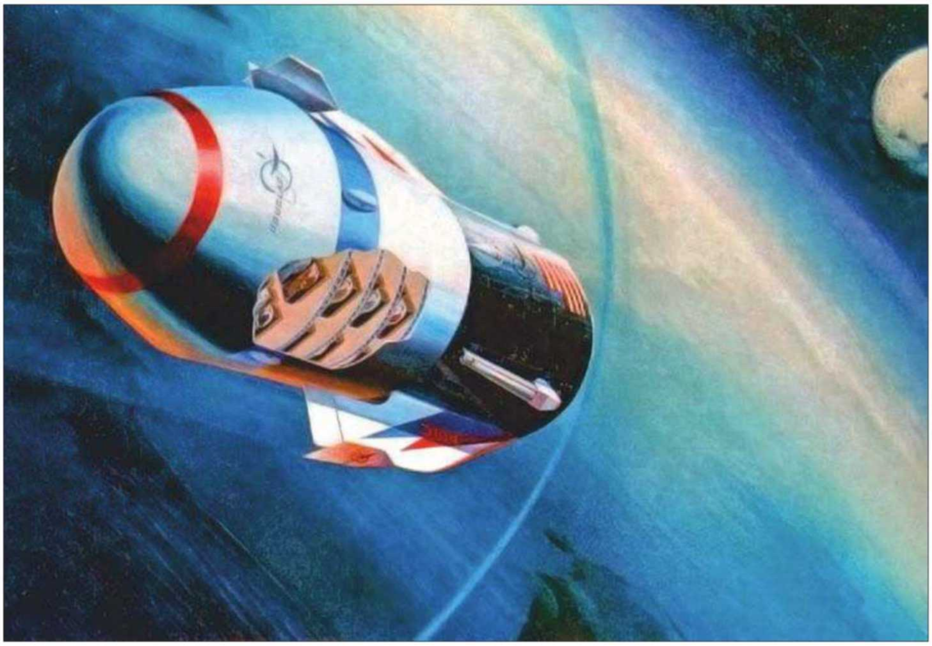
Martin Marietta responded with the design called Renova, which utilised rocket engines enclosed within an air duct with adjustable inlets. The General Dynamics proposal was for a massive SSTO spacecraft called Nexus, which was designed by Krafft Ehricke. This huge vehicle was to have an overall length of approximately 400ft (121m) and a core diameter of 150ft (45.7m), making it one of the largest conventionally-powered spacecraft vehicles ever designed. Equally impressive was the projected capability of lifting a 900 ton (816 tonne) payload to LEO. North American Aviation produced another preliminary

Below left: **Designed by Krafft Ehricke, the General Dynamics Nexus SSTO was one of the largest conventionally-powered manned space vehicles ever proposed. It had an overall length of about 400ft (121m).** General Dynamics

Below right: **North American Aviation produced several classified designs for a very large SSTO capsule vehicle which utilised external ramjets for lift. The objective was to deliver very substantial payloads to orbit.** USAF







Above left: **Aerospace engineer Philip Bono stands next to a scale model of the Douglas Pegasus spacecraft.** Douglas

Above right: **A Pegasus intercontinental transport vehicle begins to re-enter the Earth's atmosphere. The designers believed this vehicle was technically feasible and could have been in service by the 1980s.** Douglas

SSTO design for a large capsule called the Air-Augmented Vertical Takeoff & Landing Rocket-Launched Vehicle.

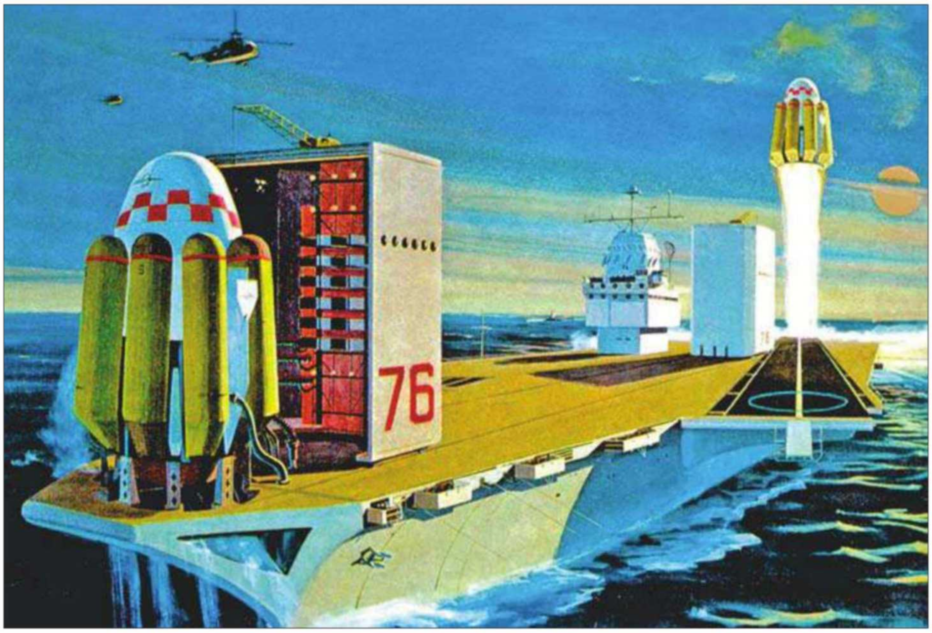
Primarily powered by rocket engines, North American's project was to be equipped with external ramjets for additional lift at certain stages of the flight profile. The concept showed sufficient promise to be initially classified as secret by the Department of Defence, and in common with the other projects it was expected to deliver a payload of several hundred tons to LEO. NASA considered these SSTO proposals, but they were expensive and probably too unconventional to generate any real change of thinking within the Administration.

Development work continued at Douglas and by early 1964 Philip Bono's team had produced plans for the Reusable Orbital Module-Booster & Utility Shuttle (ROMBUS), which was seen as a possible successor to Apollo. The most important new feature of ROMBUS was its unique and very advanced plug-nozzle rocket engine, which would be used as an actively-cooled heat shield during re-entry. This SSTO concept carried eight jettisonable liquid hydrogen tanks that were disposable but could be made recoverable if it was found to be cost effective. The initial version of ROMBUS was 95ft (29m) in length with a core diameter of 78ft (23.7m), and the spacecraft was designed to make a ground landing on four retractable struts. By 1966 ROMBUS had evolved into a very sophisticated blunt-nosed capsule called Pegasus fitted with re-entry stabilisation fins.

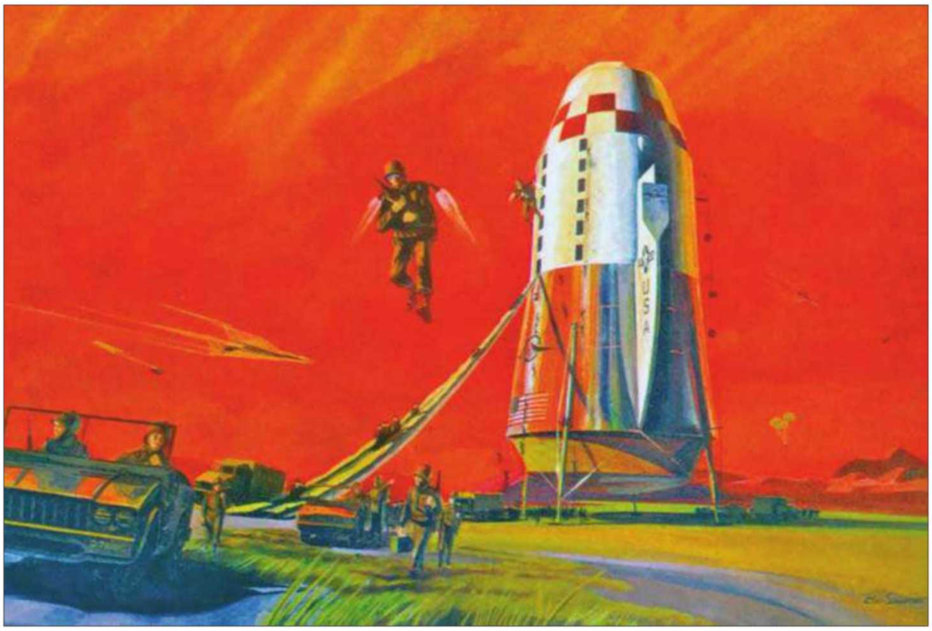
Progress was also being made with the propulsive system and Rocketdyne had now completed a full engineering model of an evolutionary improvement to the plug-nozzle design called a variable thrust aerospike engine. Pegasus was designed as an intercontinental transport vehicle with orbital capability and several variants were considered for different payloads. Bono believed that this spacecraft was technically feasible using existing engineering methods and could easily be in service by the mid-1980s. The basic version of Pegasus would carry 172 passengers on four decks and much of the original sales pitch talked about routine high-speed travel, such as journeys from London to Tokyo in thirty-four minutes or Los Angeles to Singapore in about the same length of time. While this kind of intercontinental flight might become possible at some point in the future, it should be noted that the media rehashes the idea of ultra-rapid transit for ordinary paying passengers every time a new hypersonic aircraft or spacecraft is announced.

Another version of Pegasus was proposed for intercontinental cargo deliveries or to lift an estimated 200,000 lb (90,718kg) payload to a 347-mile (560km) orbit with a 28° inclination. This vehicle measured 114ft (34.7m) in length and had a core diameter of 50ft (15.2m). It would have a total mass of 3,350,000 lb (1,519,534kg), and the plug-nozzle/aerospike propulsive system would produce a lift-off thrust of 4,203,900 lb (18,700kN). Soon after Pegasus was unveiled it began to attract interest from the military as a high-speed troop transporter. One enthusiastic campaigner for the development of a Pegasus military transporter was General Wallace M Green Jnr, who commanded the US Marine Corps and was a member of the US Joint Chiefs of Staff. He suggested building a vehicle based on Pegasus that was capable of rapidly conveying a full 1,200 strong battalion of marines to a distant battlefield. The idea was taken seriously by his colleagues and, as a consequence, Douglas was asked to explore the possibility. Design work was soon under way and Bono's team came up with two new vehicles to serve as troop carriers.

Given the overall name Ithacus, the smaller Ithacus Junior variant would be a straightforward development of Pegasus capable of carrying 260 troops and a modest amount of equipment over an intercontinental distance. Bono proposed launching Ithacus Jnr rocketships from the deck of a USS *Enterprise* class nuclear-powered aircraft carrier and he suggested using the ship's reactor to power an onboard processing plant for rocket fuel, with seawater being transformed into liquid hydrogen and oxygen. The Douglas team estimated that enough fuel for one flight could be manufactured in approximately four days. Each Ithacus Jnr would be housed in a weatherproof shelter which would slide back before launch. In addition the ships deck would be extensively modified to deal with the heat and sound produced by each launch. The two



One of many concepts considered by Philip Bono's team at Douglas was the idea of using a USS *Enterprise* class nuclear-powered aircraft carrier as a mobile launch platform for the Ithacus Jnr spacecraft. Douglas



A Douglas Ithacus transporter disembarks troops at a pre-selected landing site. Douglas

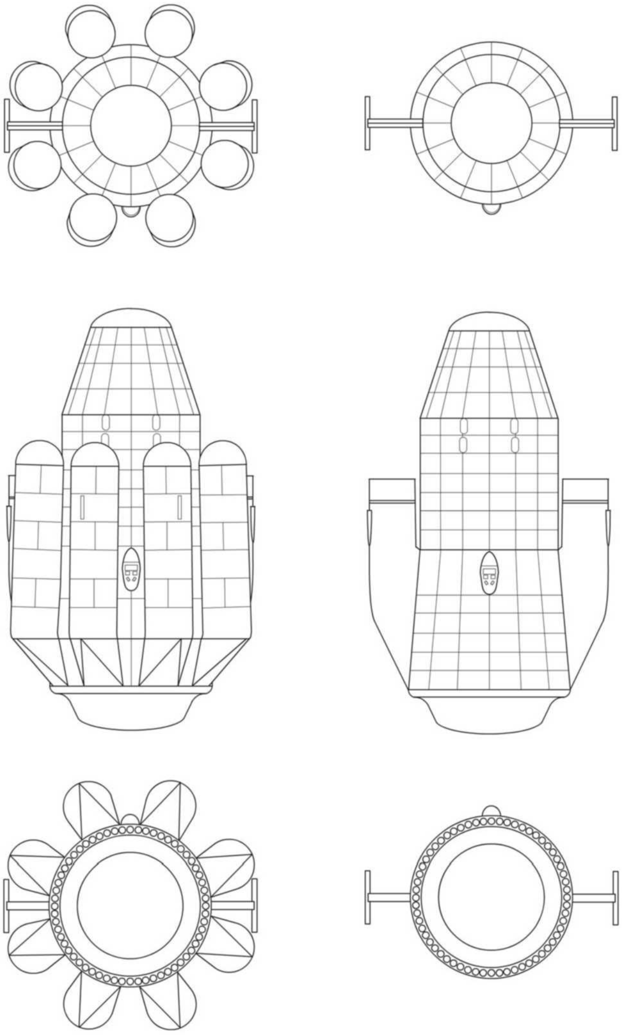
vehicles carried might lift off within minutes of each other, one acting as the troop transporter while the other carried equipment. It was claimed that this hugely expensive floating launch platform would be less vulnerable to attack than a land-based installation, but the advantage of a sea based system would appear minimal, even in a full scale war.

The much larger version of this spacecraft was called Ithacus Senior. This would be launched from land bases and could reach any part of the globe. It might also be briefly parked in orbit awaiting a final landing site selection. Ithacus Snr would carry 1,200 troops (as requested by General Greene) or 130 tons (118 tonnes) of equipment to a war zone. Its length was 210ft (64m) and core diameter 80ft (24.3m). As a troop transporter, six pressurised decks inside the spacecraft would each carry two hundred soldiers and their personal equipment. The four crew members would control operations from within an escape capsule that was designed to operate in emergency situations at all altitudes from launch to orbit. This module would be equipped with four solid-fuel rocket boosters and fitted with small stabilising fins to assist during descent. Ithacus Snr would have an enormous engine thrust of 18,036,420 lb (80,067kN) and a colossal lift-off mass of 14,028,000 lb (7,014 tons/6,363 tonnes).

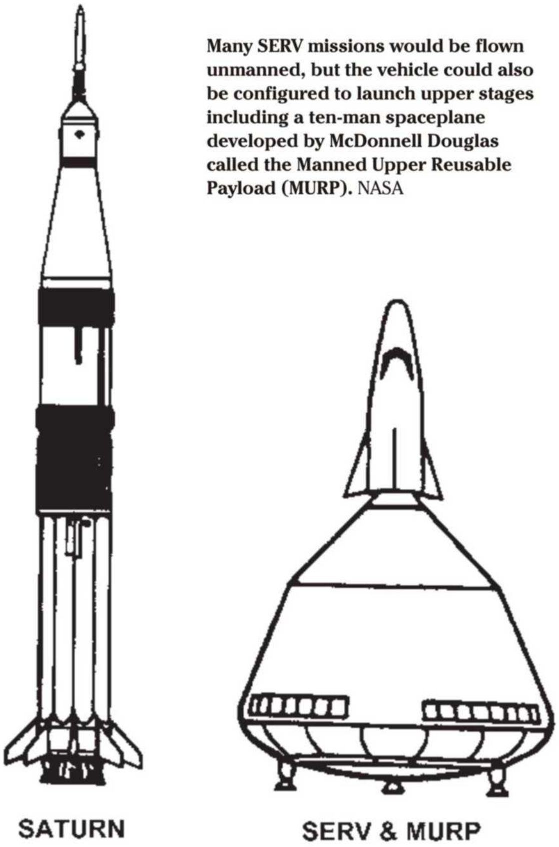
Unfortunately, several significant problems seem to have been glossed over, including noise, recovery and vulnerability. Perhaps the biggest concern involved the unproven engine technology which would have been very noisy and, in the case of Ithacus Snr, was expected to be some 2.5 times greater than a Saturn V rocket. Such high acoustic levels would have damaged the vehicle's structure, endangered personnel onboard and generated major problems at the launch site. In an attempt to address these concerns the engineers at Douglas suggested that Ithacus Snr (and other large SSTO spacecraft) could be launched from a specially constructed 500ft (152m) diameter parabolic launch pad built from concrete and which would be flooded. They also claimed that it would be possible to protect the vehicle from damage and fully insulate passengers.

Assuming it was possible to resolve these issues, there might be major problems recovering an Ithacus Snr vehicle from an improvised landing site. Douglas engineers suggested that both versions of Ithacus could be partially refuelled and flown to a coastal area or waterway for return on a barge. However, forgetting the possibility of having to undertake this in a hostile environment, the engine noise generated by Ithacus Snr might still exceed acceptable parameters at the landing site, even if the vehicle was considerably lighter and able to fly with greatly reduced engine thrust. Then there is the question of vulnerability during descent. An Ithacus would present itself as a large hot target with little or no defence against surface-to-air missiles. Certainly, the loss of a single Ithacus carrying an entire battalion of troops would prove catastrophic to the majority of special operations. Although an interesting idea, the Ithacus troop transporter continues to border on a science fiction concept.

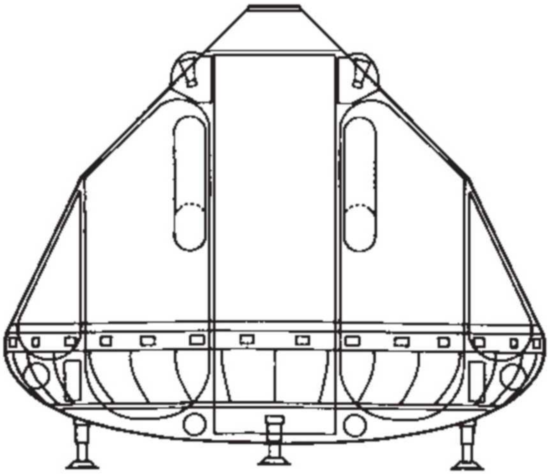
Initial interest in Bono's spacecraft had faded by late 1970 when the Chrysler Corporation's Space Division in Louisiana produced an unusual proposal for NASA's Space Shuttle programme. This took the form of a large capsule with an SSTO capability that utilised elements of Bono's earlier concepts. Known as the Single-stage Earth-Orbital Reusable Vehicle (SERV), this proposal developed by Charles Tharratt and his team received a

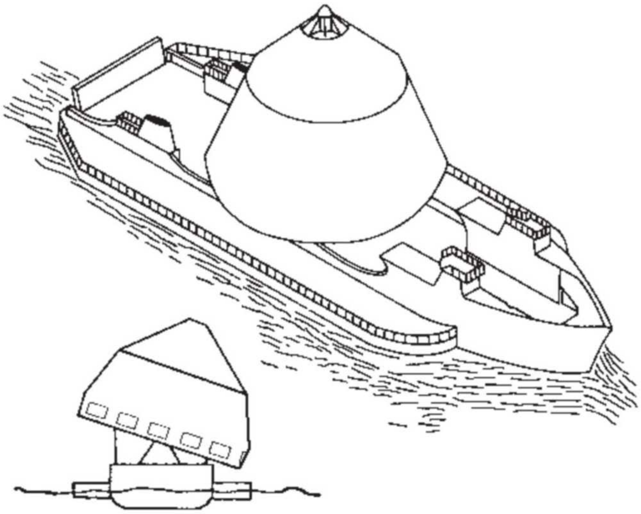


Douglas Ithacus Military orbital space transporter. Chris Gibson



Many SERV missions would be flown unmanned, but the vehicle could also be configured to launch upper stages including a ten-man spaceplane developed by McDonnell Douglas called the Manned Upper Reusable Payload (MURP). NASA





Above: **Construction of the Chrysler SERV would have taken place at the Michoud Assembly Facility (MAF) where the Saturn V first stage was built. It would have been transported by a *Bay* Class vessel owned by the West India Shipping Company to the Kennedy Space Center.** NASA

Left: **Intended to compete with the Douglas SSTO concepts produced by Philip Bono's team, the Chrysler Single-Stage Earth-Orbital Reusable Vehicle (SERV) was a massive capsule powered by a plug-nozzle aerospike engine. The company proposed this as an alternative to the Space Shuttle.** NASA

$1.9 million NASA study contract (NAS8-26341). SERV would have a launch mass of approximately 2,000 tons (1,814 tonnes) and use a twelve-module aerospike engine delivering 5,800,000 lb (25,800kN) of thrust. The vehicle's length was 66ft 7in (20.29m) and it had a core diameter of 89ft 9in (27.37m) giving it the appearance of a massively scaled-up Apollo capsule. Twenty-eight jet engines would be used at subsonic speeds for vertical landing and they would allow a brief period of hover. SERV would be equipped with four short stubby landings legs and the centre of the vehicle would accommodate a large payload bay, measuring 60ft (18.2m) by 23ft (7m). Most SERV missions would be undertaken without a crew and the vehicle would operate in an automated mode.

It was also proposed to configure SERV as the launcher for a smaller vehicle called the Manned Upper Reusable Payload (MURP). This was a compact ten-man spaceplane developed by McDonnell Douglas for the Phase-A shuttle studies. As a military development of the SERV system the spaceplane would have provided the cross-range required by the USAF, which was not available from SERV. When the study period for SERV had ended, NASA and the USAF remained unconvinced about the merits of this unusual design. Neither could be swayed from the idea of a more conventional Shuttle design and the SERV project died.

In late 1965 Boeing's Southeast Division at Huntsville, Alabama became another contractor to begin design work on a heavy lift SSTO spacecraft that used the plug-nozzle/aerospike propulsion system. Within three years Boeing had completed two proposals that could be configured for many different uses. The basic model was the Multipurpose Large Launch Vehicle (MLLV) which had a core diameter of 57ft (17.3m) and a starting length of 220ft (67m). MLLV was designed to lift a 235 ton (213 tonne) payload to a 115-mile (185km) orbit, but this could be significantly improved with the use of an additional eight 21ft 8in (6.6m) strap-on solid fuel boosters, perhaps allowing a maximum payload of 925 tons (839 tonnes) to be lifted into LEO.

Boeing also developed plans for a scaled-up version of this concept called the Advanced Multipurpose Large Launch Vehicle (AMLLV). This huge spacecraft would have a core diameter of 72ft (22m), a length of about 300ft (91.5m) and the anticipated ability to lift 500 tons (454 tonnes) to a 115-mile (185km) orbit. Equipped with twelve 21ft 8in (6.6m) strap-on solid fuel boosters, this would allow an impressive payload to LEO capability of 1,870 tons (1,696 tonnes).

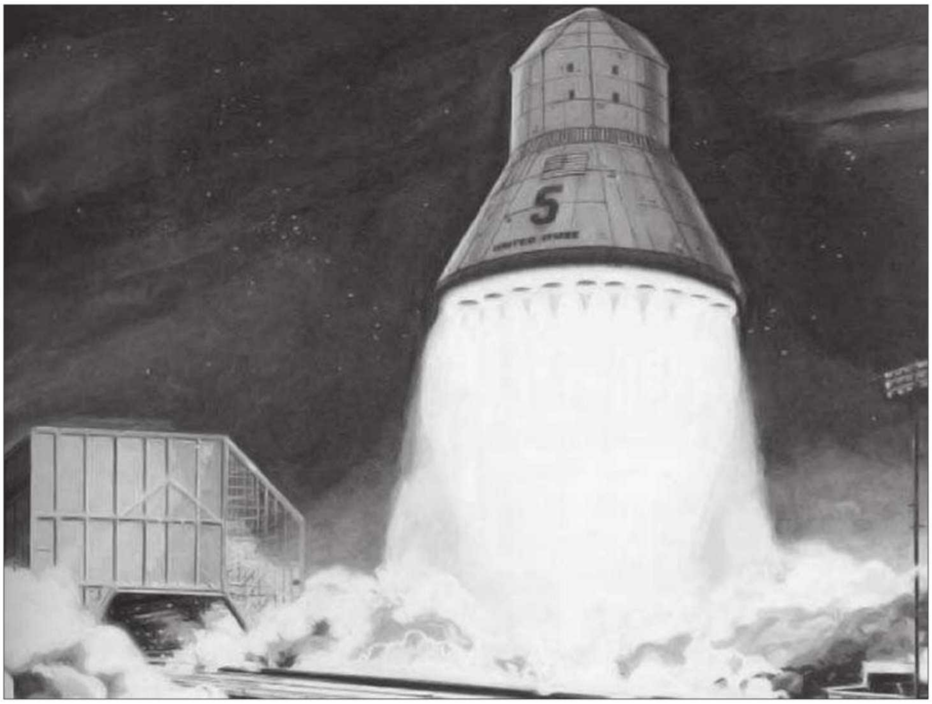
Like SERV, the study failed to attract any serious interest from NASA or the USAF and was largely forgotten by the end of 1971. However Boeing revived the large SSTO concept during the mid-1970s as part of the NASA solar powersat studies. This new capsule design known as Leo was powered by a rather complex system of forty-eight rocket engines utilising two different fuel systems. The vehicle's heat shield would be water-cooled during re-entry and the engine nozzles were protected by steam ejection. But one serious problem that accompanied the large Bono designs also applied to the Boeing Leo, excessive noise. It meant that lift-off would have to take place from an artificial lagoon some distance from all existing facilities at Cape Canaveral.

Leo was the last serious proposal from any major defence contractor for a very large SSTO spacecraft and the brute force approach was finally abandoned. The plug-nozzle propulsive system envisaged for many of these SSTO vehicles promised much but is still unproven, although it is conceivable that designs for large SSTO VTOVL spacecraft will re-appear at some point in the future.

Delta Clipper

Maxwell White Hunter II (1922-2001) had a long history of involvement with rockets, missiles and spacecraft. In the 1950s and early 1960s he worked for Douglas on many projects including the Honest John battlefield missile, the Nike Ajax and Hercules surface-to-air missile systems, the Sparrow air-to-air missile, the Thor IRBM and various SSTO spacecraft concepts. He became a high-level government advisor on space policy during the 1960s but soon decided to rejoin the aerospace industry, accepting a position with the Lockheed Missiles and Space Company (LMSC).

In the late 1980s LMSC carried out several studies for a vertical take-off and vertical landing (VTOVL) SSTO spacecraft, which had previously been independently designed by Max Hunter over a period of many years. Hunter proposed a fully re-usable SSTO vehicle with a mass of about 250 tons (227 tonnes) powered by a number of RL-10 rocket engines. However, an internal Lockheed review of his work concluded that the project was unsuitable for development and the study received no further support. Soon after this Max Hunter retired and then teamed up with Gary Hudson, the founder of Pacific American Launch Systems and designer of the Phoenix series of SSTO spacecraft. Together they continued to evolve Hunter's concept, which was now called Spaceship Experimental (SSX). In the wake of the STS-33/51-L Challenger Shuttle loss on 28th January 1986, the Department of Defense (DoD) was examining a number of proposals for new systems capable of launching military satellites at short notice during a period of national emergency. This made an affordable re-usable SSTO particularly



The Boeing Leo lifts off. This very large SSTO spacecraft concept was produced in the mid-1970s during NASA's Solar Powersat Studies. Boeing

Left: **Test flight of the McDonnell Douglas DC-X demonstrator at the White Sands Missile Range.** NASA

Right: **The small McDonnell Douglas DC-X prototype built at Huntington Beach in California undergoes pre-flight checks at White Sands.** NASA

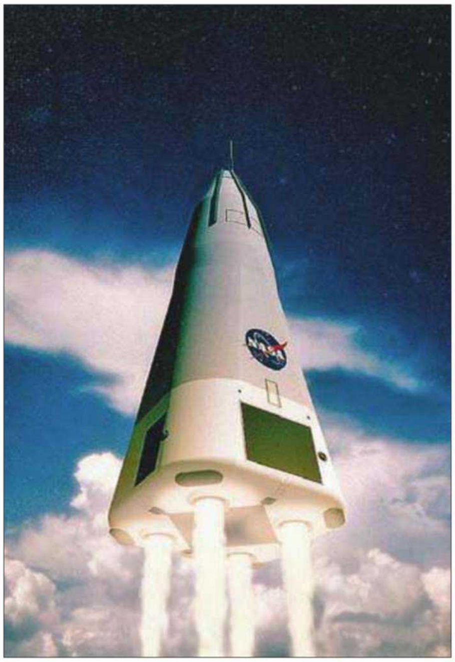
interesting and, using his government contacts, Max Hunter managed to secure official funding for the development and construction of a proof-of-concept demonstrator.

The revised version of SSX would be called Delta Clipper X (DC-X) and this name is understood to have been inspired by the Douglas DC-3 piston airliner which was often called the Clipper; the X was added for experimental. The only thing left was to find a suitably experienced contractor to construct a one-third sized vehicle. In August 1991 McDonnell Douglas Aerospace at Huntington Beach, California was awarded a two-year $58 million government contract to build a prototype DC-X that would be used to test and develop flight control systems.

Simplicity of operation was a key factor with the vehicle only requiring three personnel for ground handling and flight operations. The DC-X was 45ft (14m) long and had a core diameter of 13ft 5in (4.1m). Four throttleable (30 to 100%) RL-10A-5 rocket engines running on liquid hydrogen and liquid oxygen would provide a maximum thrust of 50,000 lb (222kN), and the vehicle lift-off mass was 35,970 lb (16,315kg). DC-X would be equipped with a reaction control system and most of the airframe was built from aluminium. Performance figures are not especially relevant to this craft since it was designed to test various new systems under modest conditions, but DC-X was capable of reaching an altitude of at least 30,000ft (9,144m). NASA arranged for testing to be conducted at the White Sands Missile Range (WSMR) and the vehicle was completed and ready for trial flights by the summer of 1993.

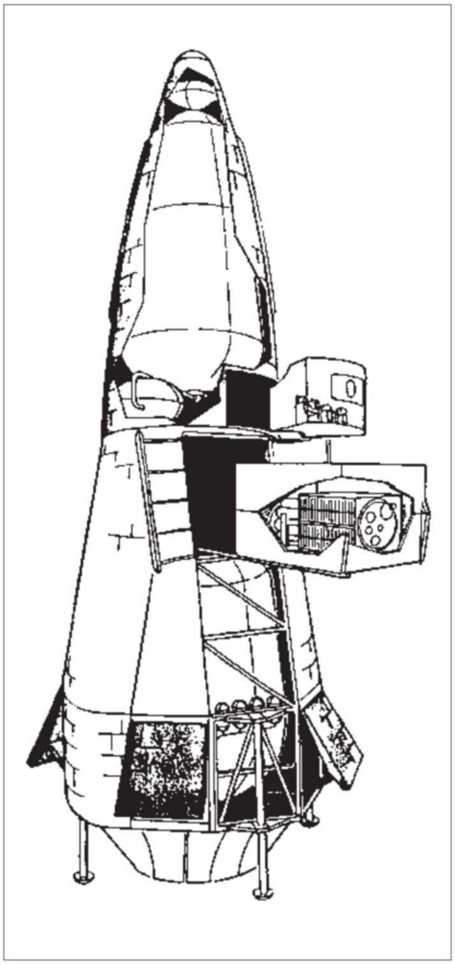
The first test flight took place on 18th August 1993 and trials continued until 30th September, when funding problems brought the project to a standstill. Four initial test flights had been made to assess handling and low-altitude hover, although various technical problems arose which is hardly surprising. Phase two of the test programme had to wait almost a year and resumed on 20th June 1994. The DC-X reached an altitude of 2,854ft (870m) in a flight lasting 136 seconds and the first trial of the second series was judged a significant success. The next flight took place on 27th June 1994, but there was an in-flight hydrogen gas explosion and the test was aborted. Fortunately the damage was not too severe, but this accident set the programme back by many months and the next test did take place until 16th May 1995. The project now appeared to be back on track and continued to make progress until 7th July 1995 when a very hard landing caused the aeroshell to fracture. As a result, the DC-X was returned to McDonnell Douglas at Huntington Beach where it underwent repairs and received a number of minor but useful upgrades. These included a lightweight graphite-epoxy liquid hydrogen tank, an aluminium-lithium LOX tank built by MD's new trading partner Energia in Russia, and a newly-designed graphite-aluminium intertank, all of which provided a very useful overall weight saving of 1,366 lb (620kg). In addition a more advanced reaction control system developed by Aerojet was installed and the modified DC-X was assigned the new designation DC-XA.

The McDonnell Douglas DC-XA returned to WSMR in March 1996 and soon began a third



Artwork showing the DC-X in flight. NASA

The proposed McDonnell Douglas DC-Y, which might have succeeded the DC-X. USAF



series of test flights. Unfortunately, disaster struck on 31st July 1996 when a landing strut failed to deploy as the vehicle touched down and it tipped over. Then the LOX tank exploded and DC-XA was destroyed. The strut failure was due to a disconnected hydraulic line and an investigation undertaken by NASA concluded that the loss was entirely due to human error. But the DC-X programme was abandoned, despite plans for a more advanced unmanned prototype vehicle. This would have been a larger version of the Delta Clipper called DC-X2 (and SX-2 by the US Department of Defense). DC-X2 was a VTOVL vehicle with an overall length of 78ft (23.7m), a core diameter of 16ft 5in (5m) and a total mass of 185,000 lb (83,914kg). A cluster of enhanced RL-10A-5 rocket engines provided a lift-off thrust of 200,000 lb (889.6kN), while handling, maintenance and testing would be dealt with by the same number of personnel responsible for the DC-X.

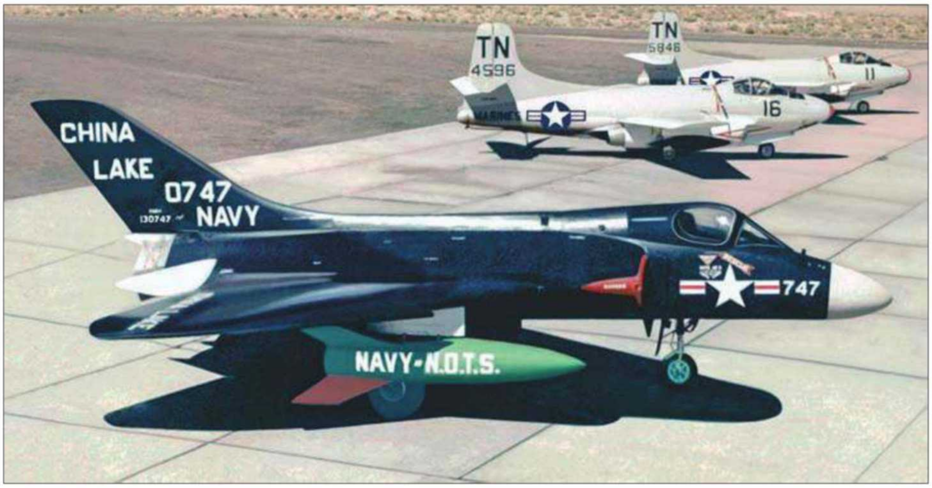
DC-X2's performance was expected to be significantly better than the DC-X and this vehicle would have the ability to briefly reach an altitude of 112 miles (180km) and achieve a maximum speed of about Mach 7. If the DC-X2 proved successful, it was hoped that by the turn of the century both NASA and the USAF would fund development of a full-sized spacecraft called DC-Y that was conceived in 1993. This was to be a pre-production version of a new vehicle with an overall length of 150ft (45.7m) and a core diameter of 30ft (9.1m). Total mass would be 1,000,000 lb (453,592kg) and eight liquid-fuelled engines would provide a lift-off thrust of 1,198,277 lb (5,330kN). The DC-Y would have the ability to deliver a 9,900 lb (4,490kg) payload into a 186-mile (300km) polar orbit or a 19,800 lb (8,981kg) payload to an equatorial orbit. After re-entry, DC-Y would have slowed to subsonic speed by the time it reached 70,000ft (21.3km) to minimise the effects of supersonic boom. The DC-Y could operate with or without crew members but would normally be flown by two astronauts. Payloads could be cargo or passengers to orbital or intercontinental destinations.

Aside from launching satellites the military roles envisaged for the DC-Y are less well defined, but Hunter claimed that the DC-Y would possess adequate cross-range performance to satisfy all USAF needs. To achieve this, the spacecraft would re-enter the atmosphere nose first, although it did mean that some parts of the vehicle would require additional thermal protection. The cost of fully developing the DC-Y and providing four operation vehicles was estimated to be about $5 billion in 1995 and comparable to the development of a new airliner. The Delta Clipper was an interesting design with many good qualities and it looked more like a proper spaceship from a sci-fi movie. It had many innovative features but was unable to attract further funding after the accident. This is the only SSTO VTOVL concept that has moved beyond the drawing board and its design can be traced back to the earliest design work at Douglas. It was a step in the right direction, but the project met with considerable resistance and never received the level of support it deserved.

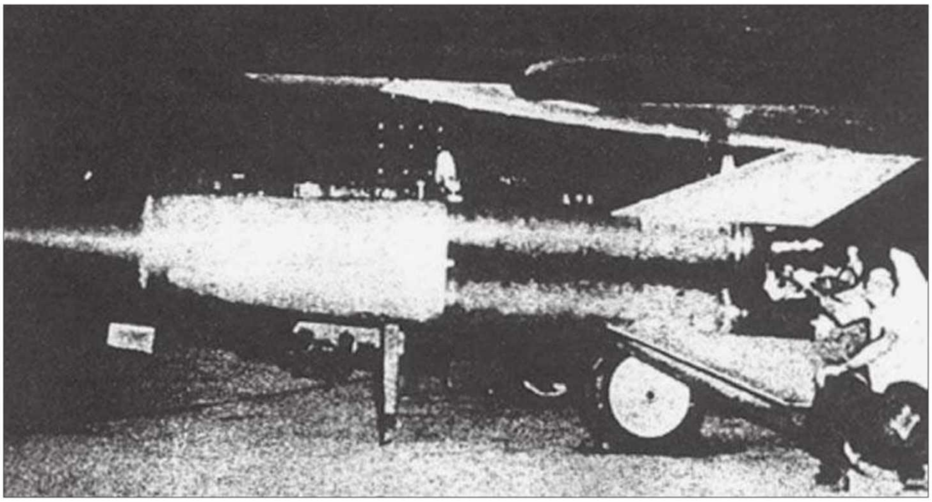
ASAT Weapons

After the launch of Sputnik in 1957, a US Navy design team working at the Naval Ordnance Test Station (NOTS) at China Lake in California began a classified programme known as Project Pilot to develop an aircraft-launched rocket that was capable of placing a small satellite in LEO. This compact multi-stage vehicle was called NOTS-EV-1, but the project received the unofficial name of Notsnik, a combination of the words NOTS and Sputnik. The initial design for NOTS-EV-1 was a five-stage air-launched vehicle using solid propellant rockets that powered the Army's Sergeant missile. Unfortunately, inter-service co-operation could be difficult at times and the Army rejected the Navy's request for rocket motors, so the NOTS scientists turned their attention to adapting readily available hardware.

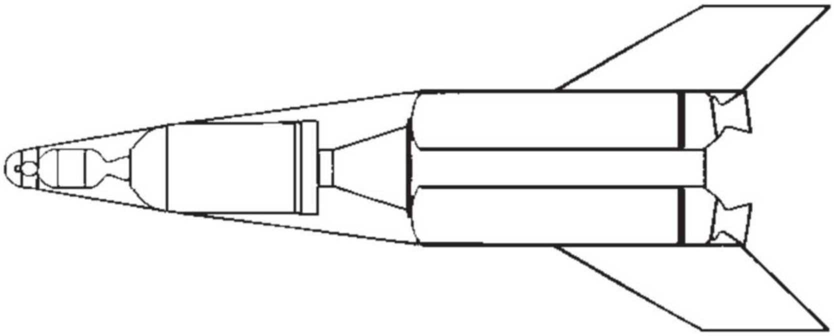
Confident they could build an air-launched rocket capable of placing a very small 2.3 lb (1.04kg) satellite into a 1,400 mile (2,253km) high orbit, the project received a modest $300,000 dollar grant at the beginning of 1958. This was on the understanding that a vehicle would be ready for testing by the middle of the year and the Navy's Bureau of Ordnance (BuOrd) hoped to launch a small Project Pilot satellite in August 1958 to gather data during the anticipated Project Argus high altitude nuclear trials. The longer-term aim of Project Pilot was to develop the basic technology needed for the rapid deployment of reconnaissance satellites and possibly anti-satellite weapons. The lightweight, very compact circular shaped Notsnik satellites had a diameter of 8in (200mm) and were built at China Lake. Battery powered, they carried little more in the way of instruments than a crude (although state-of-the-art) infrared television camera intended to demonstrate the ability to undertake orbital imaging. Nevertheless, because of the anticipated future use of orbital reconnaissance systems, Project Pilot received a top-secret classification which remained active until 1994.



A modified Douglas F4D-1 Skyray fighter based at China Lake. The rocket shown in the photograph is believed to be an inert dummy built for air-carriage trials during Project Pilot. US Navy



Poor quality photograph of the NOTS-EV-1 multi-stage rocket positioned beneath the launch aircraft. US Navy



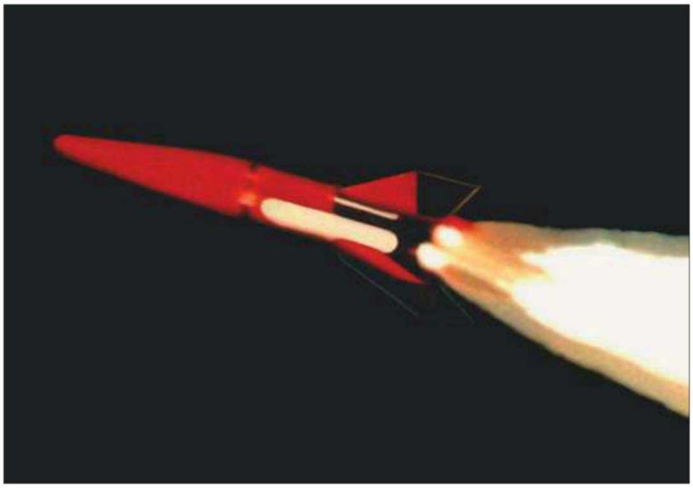
Drawing showing the multi-stage configuration of the NOTS EV-1 rocket. Bill Rose

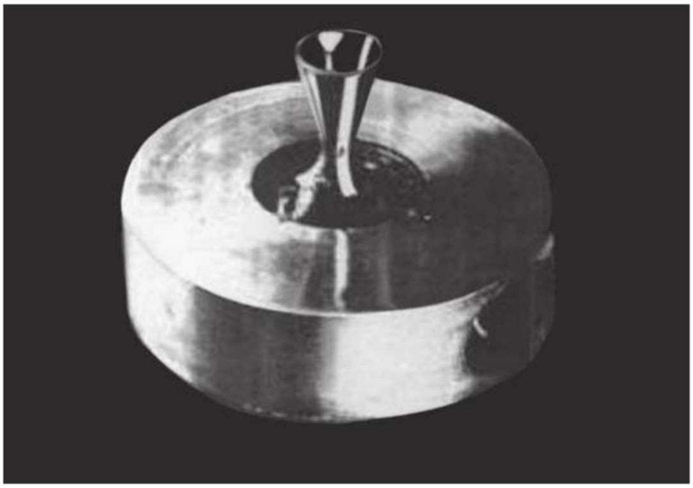
The revised NOTS-EV-1 rocket now used first and second stages built from a common airframe and both were powered by two HOTROC solid-fuelled rockets producing a total thrust of 28,400 lb (126.3kN) for 4.86 seconds. These engines were normally used for the Navy's ASROC anti-submarine weapon. Allegheny Ballistic Laboratory built the ABL-241 solid fuel rocket that propelled the third stage and this was derived from the X-248 rocket motor produced for the NRL Vanguard rocket. It provided 2,720 lb (12kN) of thrust for thirty-six seconds. The fourth stage used a NOTS-100 solid fuel rocket rated at 1,155 lb (5.1kN) thrust with a burn time of 5.7 seconds and the fifth stage used a small NOTS 3in (76mm) solid fuel rocket providing 172 lb (765N) of thrust for one second. The overall length of the NOTS-EV-1 was a modest 14ft 4½in (4.38m), it had a core diameter of 30in (762mm) and a finspan of 5ft 5in (1.65m); the vehicle weighed 2,100 lb (952kg).

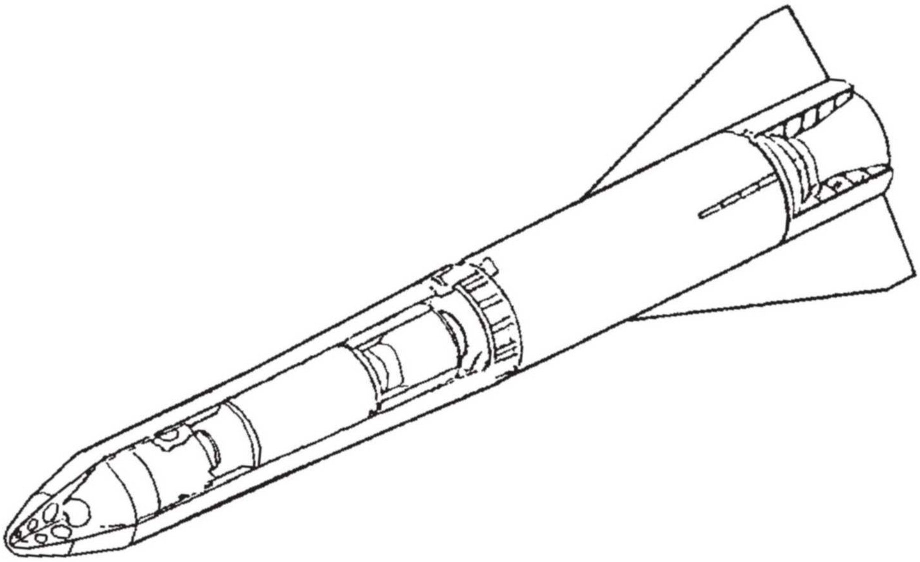
The initial ground test involving the first two stages was undertaken on 4th July 1958 at China Lake and the vehicle exploded one second after ignition. This was followed by a second test on 18th July 1958 which also resulted in a pre-lift-off explosion. Satisfied that the structural failure problem would not be an issue with air-launches, a full Project Pilot mission was attempted on 25th July 1958. The rocket was carried beneath a Douglas F4D-1 Skyray fighter (130747) modified for specialised test flights which left China Lake and flew to a US Navy testing area above the Pacific Ocean. Travelling at a speed of 460mph (740km/h) the F4D-1 executed a 50° climb and released the NOTS-EV-1 rocket at 41,000ft (12,496m) in a nuclear bomb toss manoeuvre. The launch went well and the rocket was visually tracked, but no radio signal was received from the small satellite and its fate is unknown, although it could have reached orbit.

Between 12th August and 28th August 1958 two further ground tests were undertaken with negative results and a further five air-launches took place. Four of the air-launched rockets failed and one may have reached orbit, although radio contact was lost and it remains a matter of debate as to whether the US Navy actually managed to orbit a satellite during this period. Project Pilot came to an end in August 1958 and, although it had not been a total success, a great deal of useful experience had been gained from the programme. US Navy scientists had designed and built a remarkably small orbital launch system at a bargain basement price, so it was decided to proceed with a follow-on programme called Project Caleb (or NOTS-EV-2), which received the unofficial title Notsnik 2.

The new rocket for this project was an improved four-stage version of NOTS-EV-1 and the plan was to develop an affordable system that could place small reconnaissance satellites into orbit, with the potential for development into an ASAT weapon.







Top left: **A NOTS-EV-1 is successfully launched from a modified F4D-1 Skyray fighter.** US Navy

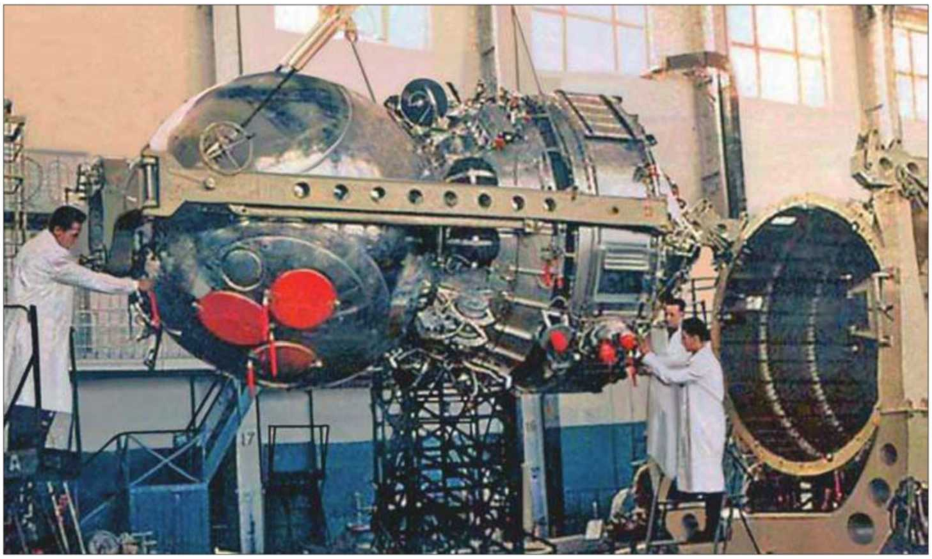
Top right: **The small 8in (200mm) diameter Notsnik satellite carried a battery-powered infrared camera to demonstrate orbital imaging. Although crude by present day standards, this was state-of-the-art technology in the late 1950s.** US Navy

Left: **The multi-stage Project Caleb rocket (NOTS-EV-2) was sometimes referred to as Notsnik 2.** US Navy

Below left: **In late 1961 three air launches of modified NOTS-EV-2 rockets were made from a McDonnell F4H-1 Phantom above the Pacific. These trials received the project name Hi-Hoe.** US Navy

The HOTROC booster stages which had caused so many problems were scrapped and NOTS-EV-2 used a NOTS-500 first stage producing 11,995 lb (53.35kN) of thrust for thirty-four seconds and an (X)ABL-248 second stage with 3,097 lb (13.77kN) thrust burning for thirty-nine seconds. The third stage used a NOTS-100A (NOTS-3) rocket motor which provided 509 lb (2.26kN) of thrust for 204 seconds and the small upper stage was equipped with a NOTS-4 motor giving 158 lb (702N) for three seconds. The first air-launch of a NOTS-EV-2 using only first stage propulsion took place on the 28th July 1960. Carried to release by the same F4D-1 that was used for the earlier Notsnik programme, this test was judged a complete success. The next test of a two-stage vehicle took place on 24th October 1960 but did not go well because the second stage failed to ignite. Experiments to determine the suitability of using NOTS-EV-2 as an ASAT missile were conducted under the Satellite Interceptor Program (SIP). A number of successful ground launches took place during October 1961 and May 1962 at San Nicolas Island, California, but the details are unknown.

A Martin-built Bold Orion (WS-199B) missile carried by an adapted Boeing B-47 bomber. Initially developed to test the feasibility of air-launched ballistic missiles, the last Bold Orion trials concentrated on the possibility of developing this rocket into an anti-satellite weapon. USAF



The first Soviet-built reconnaissance satellite to reach orbit on 26th April 1962 was called Cosmos-4, although Cosmos was a blanket term for Russian satellites and this vehicle's proper designation was Zenit-2. During the 1960s the Soviet Union launched about eighty of these satellites and the Americans worked hard to find methods of neutralising them during any major conflict. RKK Energia

Eventually the USAF became concerned that it would lose overall control of military space systems and so considerable pressure was brought to bear which led to the official cancellation of Caleb. This might have been the end of the story but NOTS continued to work on the programme, which was now classed as a non-orbital experimental rocket system. Beginning on 5th October 1961 three air-launches of modified NOTS-EV-2 rockets known as Hi-Hoe were made above the Pacific using an adapted McDonnell F4H-1 (F-4B) Phantom fighter. The first two tests were failures but the third, held on the 26th July 1962, reached a maximum altitude of 725 miles (1,166km) before falling back to Earth. However, one success out of three was insufficient to keep this project afloat and no more funding was made available to Hi-Hoe.

The USAF was already studying a range of options for air-launched anti-satellite and ballistic missiles, which began in early 1958 under an umbrella programme called Weapons System 199 (WS-199). The principle contractor was Martin and the first significant development was an air-launched missile called WS-199B or Bold Orion, which had been built from various off-the-shelf components. Initially this was a single-stage configuration missile based on the solid fuel Thiokol TX-20 powered Sergeant rocket. Test launches from a Boeing B-47 bomber began in May 1958 and soon afterwards the missile was upgraded to a two-stage design with the addition of a solid fuelled Altair second stage. Bold Orion measured 37ft (11.27m) in length, it had an estimated range of 1,100 miles (1,770km) and would form the basis of the later (unsuccessful) GAM-87/AGM-48 Skybolt ballistic missile.

A parallel programme known as WS-199C High Virgo began in mid 1958 to develop air-launched ballistic missiles for the supersonic B-58 Hustler bomber. Lockheed was the principle contractor for the High Virgo missile with Convair (who built the B-58) taking responsibility for the missile's integration with the aircraft. High Virgo was a more compact single-stage missile powered by a Thiokol TX-20 solid fuel rocket providing 50,000 lb (222kN) of thrust. It measured 30ft 4in (9.24m) in length, had a diameter of 31in (787mm) and a weight of 12,000 lb (5,450kg). Its range was quite limited at 185 miles (297km) but it was capable of reaching an altitude of 250,000ft (76km) and a speed of Mach 6.

Several trial launches of High Virgo were undertaken between autumn 1958 and summer 1959 which were all largely successful. There are reports that the last launch on the 22nd September 1959 was an unsuccessful ASAT test which used a significantly modified High Virgo missile unofficially called King Lofus IV. The intended target was the Explorer IV satellite and King Lofus IV was supposed to make a close pass and secure images with a photographic nose capsule. However the orbital calculations for Explorer IV were faulty and Explorer V was hastily chosen for the fly-by, but communication with King Lofus IV was lost shortly after launch. That said it would appear that some parts of this account are untrue because Explorer V failed during second stage separation of the Jupiter C booster soon after its launch on the 24th August 1958.

While the exact details of this final High Virgo test remain unclear, the twelfth and final Bold Orion launch from a B-47 on 13th October 1959 was an ASAT test which proved very successful. Bold Orion was launched from the adapted bomber at an altitude of 35,000ft (10,700m) and climbed to make a close pass of the radiation research satellite Explorer VI. This had been launched on 7th August 1959 but failed completely on 6th October due to an electrical fault. This was a difficult mission to undertake with prevailing technology because Explorer VI had been placed into a highly elliptical 47° orbit with an apogee of 26,000 miles (41,900km), a perigee of 147 miles (237km) and an orbital period of 754 minutes. After launch a continual stream of telemetry was received from Bold Orion, which also dispensed flares to assist visual observation. The test went according to plan and radar confirmed that it passed within 4 miles (6.43km) of Explorer VI. Another version of Bold Orion called WS-199D was built to test small boost-glide models during 1959 and the idea of adapting the Minuteman ICBM for launch by the B-58, with orbital photo reconnaissance and ASAT payloads aboard, was considered briefly.

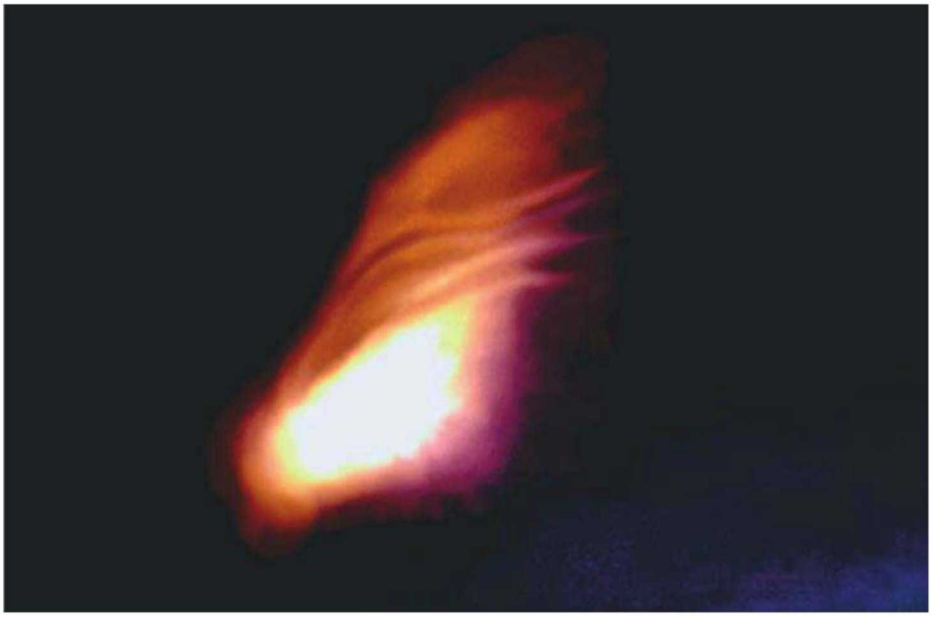
The US Military also studied the effects of high-altitude nuclear detonations which started with the Hardtack trials in 1958. During this series of tests two Redstone missiles carrying 3.8 megaton warheads were launched from Johnston Atoll in the Pacific and the high-altitude explosions gave a clear indication of the potential for nuclear ASAT weapons. At the same time a top-secret project was being conducted in the South Atlantic under the name Operation *Argus* to determine if nuclear weapons could be used to destroy orbital spacecraft. Three launches were made using Lockheed X-17A rockets equipped with small W-25 nuclear warheads which had been designed for the Genie air-to-air missile and were rated at 1.7 kilotons. The first warhead exploded at an altitude of 124 miles (200km), the second was detonated at 159 miles (255km) and the third at a very high altitude of 335 miles (539km). The tests were disclosed in 1959 but the details remained secret until April 1982. The Russians also conducted several high-altitude low yield nuclear tests with missiles launched from Kapustin Yar during 1961, but it was the unexpected side-effect of one particular US detonation above the Pacific which would demonstrate an effective way of destroying satellites that had not received a great deal of consideration up to that time.

The name of this test was Starfish Prime and it was undertaken jointly by the Defense Atomic Support Agency (DASA) and the Atomic Energy Commission (AEC) on 9th July 1962. A Thor missile fitted with a W-49 thermonuclear warhead was launched to an altitude of 248 miles (399km) above Johnston Island in the Pacific Ocean. When the 1.45 megaton warhead exploded it unleashed a massive electromagnetic pulse (EMP) that caused damage to electrical equipment within a wide area stretching from Hawaii to New Zealand. But this was an era of crude electronics and there was still a dependency on (EMP resistant) valve-based technology, so the effects were limited. Because of our total reliance on microelectronics the situation would be very different today – a similar event above a continent would destabilise the global economy.

Two smaller high-altitude nuclear tests followed Starfish Prime in late 1962 and then the overall programme (called Operation *Dominic*) was terminated after the Nuclear Test Ban Treaty had taken effect in 1963. Aside from the disruption to electrical systems on the ground, another feature of Starfish Prime had been the creation of an artificial radiation belt which destroyed the Transit B, Traac and Ariel satellites and caused damage to Injun 1, Cosmos V and Telstar. Nicholas Christofilos was a scientist working on Project Argus who accurately predicted the possibility of these effects and it was now established that a high-yield exoatmospheric nuclear explosion might be capable of disabling incoming nuclear warheads and destroying enemy reconnaissance satellites by means of EMP.

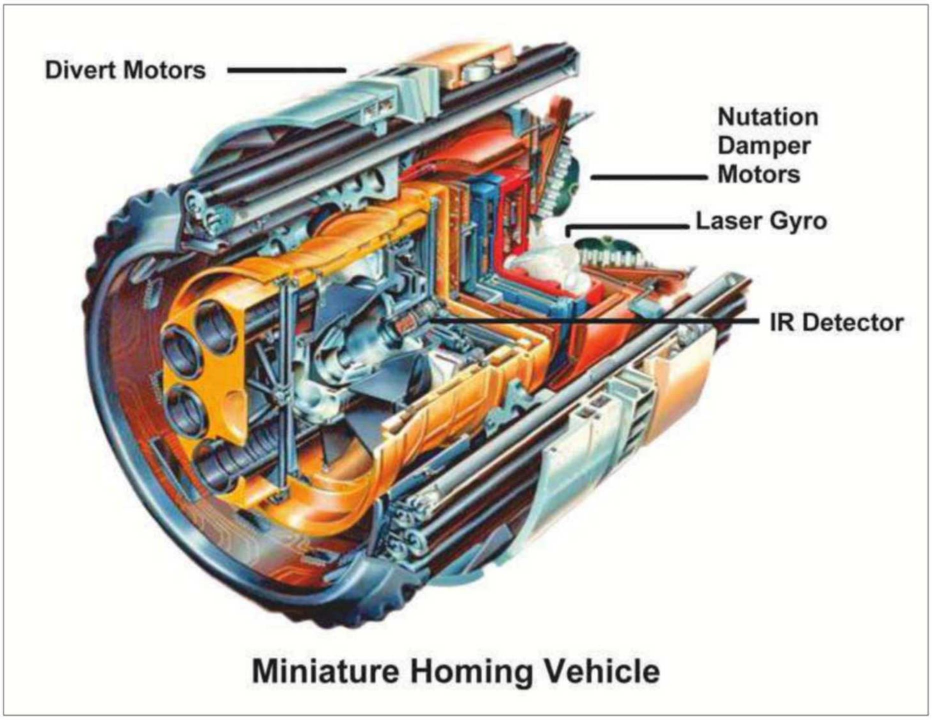
In practice the concept of protecting America from a full-scale Soviet missile attack has never been realistic or affordable, but during the early 1960s the Pentagon established the first in a planned series of anti-ballistic missile (ABM) installations at Kwajalein Atoll in the Pacific. Under Program Mudflap the Douglas-built Nike Zeus XLIM-49A anti-ballistic missile had been successfully tested in the ASAT role at WSMR during December 1962 and US Secretary of Defence Robert McNamara approved the swift deployment of this new system, which was re-designated Program 505. Equipped with a W-50 400 kiloton yield thermonuclear warhead, Nike Zeus was capable of intercepting re-entry vehicles and satellites at a height of 350 miles (564km). According to one report there was always at least one nuclear-tipped Nike Zeus on standby at Kwajalein Atoll to intercept a Soviet manned or unmanned spacecraft. Work on a more advanced missile system to replace Nike Zeus was under way by early 1963, with plans to develop cutting-edge tracking and guidance technology and a new type of enhanced radiation warhead specifically designed for exoatmospheric detonation.

Program 505 proved expensive and technically challenging and attempts to expand operations were strongly resisted by some politicians. After the Limited Test Ban Treaty came into force on 5th August 1963, bringing to an end to the testing of nuclear weapons in space, the atmosphere and underwater, several advanced projects were cancelled, although work on ABM and ASAT technology continued albeit at a reduced pace. The Nike Zeus missiles were finally retired in May 1966 and replaced by Project 437, which was operated by the USAF. Based at Johnston Atoll, this system used adapted Thors fitted with W-49 thermonuclear warheads delivering an explosive yield of 1.45 megatons. The weapon could have easily destroyed a spacecraft at a height of 435 miles (700km), although it seems that Project 437 was not all it appeared to be. Nuclear warheads were

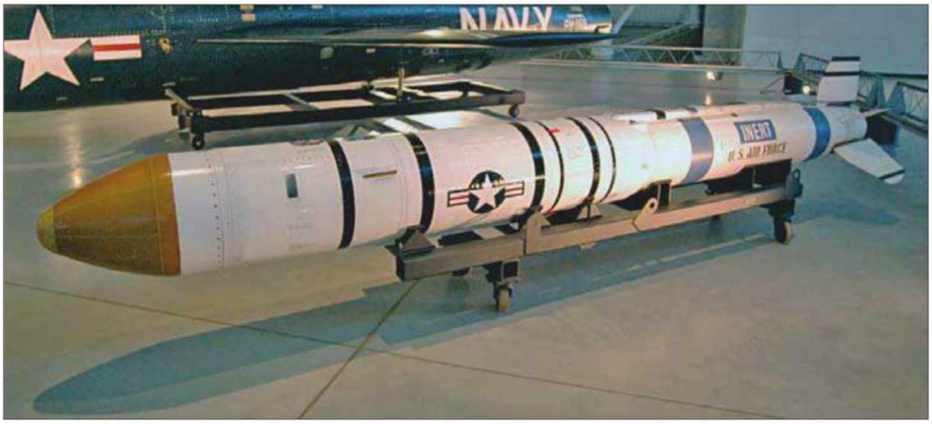


On 9th July 1962 a US Thor missile carried a W-49 thermonuclear warhead to an altitude of 248 miles (399km) above Johnston Island in the Pacific Ocean. The 1.45 megaton detonation created a massive electromagnetic pulse (EMP) which damaged electronic equipment over a wide area and disabled several satellites. US Department of Defense

The Miniature Vehicle (MV) interceptor built by Hughes, which was the upper stage of the Vought ASM-135 ASAT missile launched by an F-15 fighter. USAF



The Vought ASM-135A Anti-Satellite-Missile (ASAT) was developed for the USAF to be air-launched by a modified McDonnell Douglas F-15. USAF

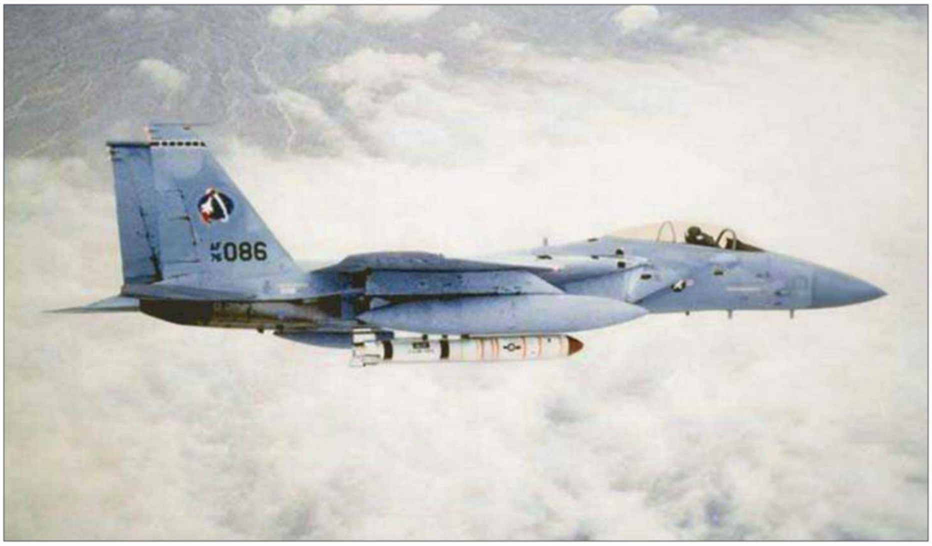


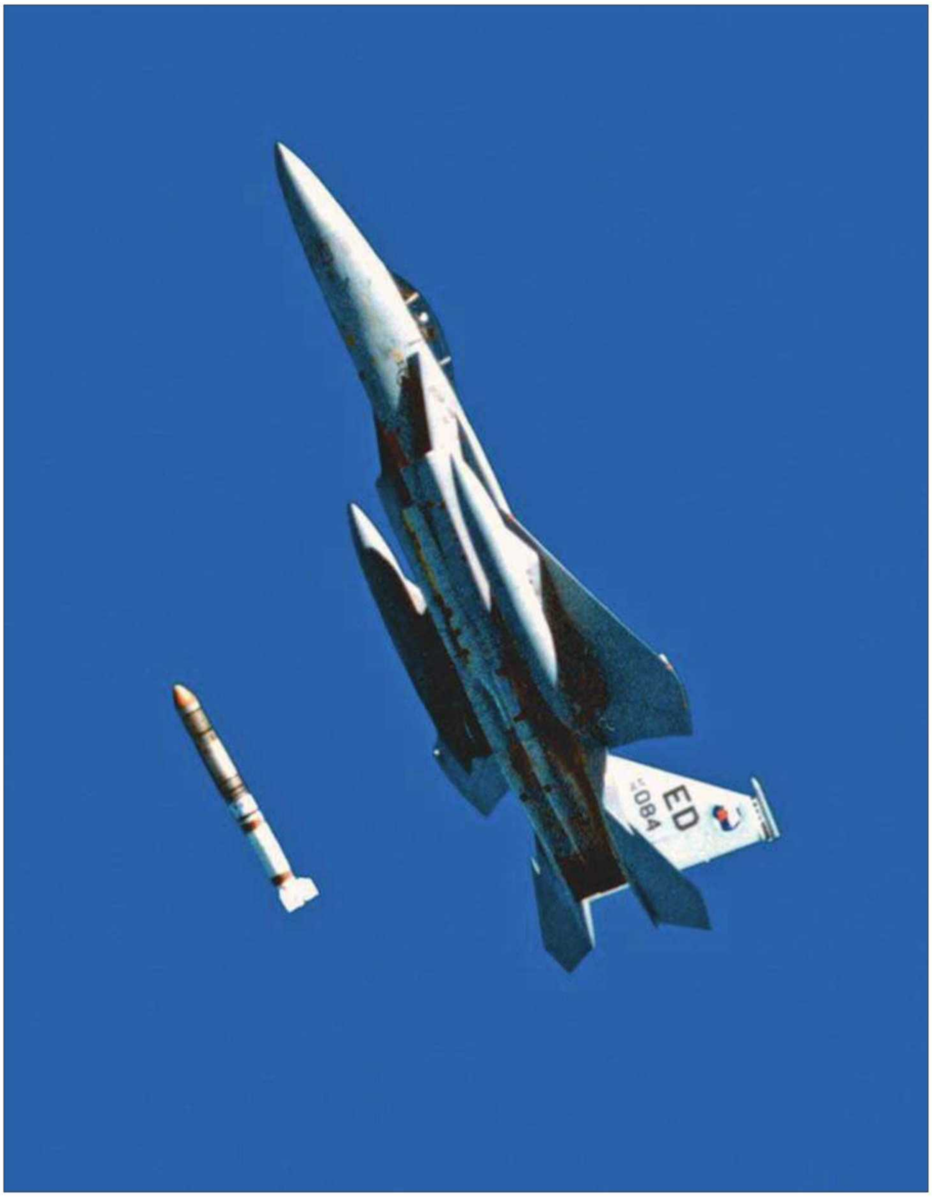
stored at Vandenberg AFB in California and it would have taken two weeks to prepare a Project 437 Thor for operational use. Furthermore, employing this weapon in peacetime would have probably triggered World War Three. That aside, four Program 437 Thor missiles were launched with specialised payloads for satellite inspection and disablement during 1965 and 1966, perhaps as part of another programme called Program 922. The payload was a sophisticated vehicle carrying a high-explosive fragmentation charge capable of destroying an enemy spacecraft, although the success of these trials is unknown.

It is also possible that these experiments were linked to an equally obscure USAF/CIA-sponsored project called SAtellite-INTERceptor or SAINT. This began in the late 1950s, probably in response to Soviet anti-satellite developments, and the programme remains largely classified. One version of the SAINT spacecraft weighed 2,425 lb (1,100kg) and would have been launched by an Atlas D/Agena B with the upper stage being used for orbital manoeuvring. SAINT would inspect foreign satellites in real-time using four television cameras, a bank of floodlights and various sensors, and had the option to disable or destroy the vehicle using spray paint or an explosive charge. A command centre would be established at NORAD's Cheyenne Mountain Complex and SAINT-equipped rockets were to be on standby at Cape Canaveral and Vandenberg. The plan envisaged a response to any suspicious satellite passing over US territory within twelve hours. The leading contractor for this project was RCA who developed all of the electronic systems and expected to progressively improve the capabilities of SAINT once testing had begun. But SAINT was technically over-ambitious, over complex and potentially very expensive. By late 1962 the USAF had lost its enthusiasm for SAINT, although interest in other ASAT systems continued.

As for Program 437, it remained officially on standby until just after 26th May 1972 when President Richard Nixon and Chairman Leonid Brezhnev signed the Anti-Ballistic Missile Treaty. This treaty also included an agreement not to attack another nation's reconnaissance satellites and formed part of the larger Strategic Arms Limitation Treaty (SALT-1). Although Program 437 was terminated in 1972, the Pentagon returned to the idea of developing a quick-response non-nuclear, fighter-launched missile for ASAT operations. Project Spike was commissioned and would be based on a two-stage solid fuel rocket derived from the Standard anti-radar missile that could be air-launched from a Convair F-106 fighter. The missile would not be equipped with a warhead and would kill its target with kinetic energy released by a controlled high-speed collision, a method that would require very high standards of tracking and guidance. The two contractors participating in Project Spike were General Dynamics (GD) and Ling-Temco Vought (LTV).

Each company built different homing vehicles that used advanced terminal guidance and small thrusters for final course correction. Several captive test flights of a Project Spike mock-up missile were made using a slightly modified F-106, but development slowed towards the late 1970s and Project Spike never reached the flight-test phase. However, LTV's design was used as the basis for a new air-launched ASAT system that met with secret presidential approval in 1977. The Soviets were developing new ASAT systems and it was felt within the White House that they needed to be shown that the US military had a similar capability that could be deployed at short notice. There were actually two new projects resulting from this political decision and the first was an air-launched ASAT weapon that could be developed relatively quickly. The second was a longer-term electronic warfare capability specifically aimed at interfering with Soviet satellites.





An F-15 carries an inert ASM-135 during a captive flight trial in the early 1980s. USAF

High-altitude launch of a Vought ASAT missile. The first and only interception of a defunct US satellite took place on 13th September 1985. USAF

In 1979 the USAF contracted Vought to develop a next-generation development of the Project Spike ASAT, with the primary aim of neutralising accessible ELINT and reconnaissance satellites during a time of crisis. Modified McDonnell Douglas F-15s would be used as launch platforms and these high-performance fighters could easily be configured to reach an altitude of at least 75,000ft (22.8km) where the missile would be released at supersonic speed under fully automated direction. The new two-stage Vought missile was designated ASM-135A and utilised a first stage propelled by a solid propellant SR75-LP-1 rocket normally used for the AGM-69 SRAM, and a second stage based on Vought's Altair III (used as a stage of the Scout B rocket) which was fitted with a Thiokol FW-4S solid fuel motor. ASM-135A was 18ft (5.48m) long, it had a core diameter of 20in (508mm) and weighed 2,700 lb (1,224kg). It would reach a speed of Mach 20 and the 'hit-to-kill' vehicle it carried could engage targets at altitudes as high as 350 miles (563km). The final stage would home in on the target using a liquid helium-cooled infrared seeker and the high-speed impact would be sufficient to virtually vaporise the enemy satellite, although the resulting debris could pose a hazard to other spacecraft in the future.

F-15A 76-0086 based at Edwards AFB was adapted for the test programme with a centreline launch rail and various modifications to its control systems. The aircraft was ready for initial trials in 1983 and a series of test flights was made carrying an inert missile to altitudes as high as 80,000ft (24,400m) in zoom climbs. With mission planning and coordination being undertaken at Strategic Air Command's Cheyenne Mountain complex in Colorado, the first live test launch was attempted on 21st January 1984. The ASM-135A did not carry the miniature hit-to-kill vehicle but the test went well. The next test on 13th November 1984 failed, but on 13th September 1985 a second F-15A (77-0084 belonging to the 6512th Test Squadron at Edwards AFB but operating from Vandenberg), launched an ASM-135A at 80,000ft (24.3km). This successfully destroyed the Solwind P78-1 (79-17A, Sat Cat Nr 11278) gamma ray spectroscopy satellite which had been launched during February 1979. Two further ASM-135A launches took place in autumn

1986 using celestial sources as their targets.

It seemed that the politicians were pleased with the results of these trials and decided that the Russians would be deterred from using their ASAT capability. But the cost of this project continued to spiral and the price of establishing two operational squadrons, each with twenty-four aircraft and fifty-six missiles at their disposal, was becoming prohibitive. These would be based at Langley AFB in Virginia and McCord AFB in Washington State, but in late 1986 the estimated cost had reached almost $5.5 billion. Vought's ASAT was now cancelled but US interest in disabling or destroying hostile satellites continued with the focus of interest switching to other projects within the black domain. These embraced electronic warfare techniques and the development of high-power directed-energy weapons.

One interesting and distantly related development is the recent proposal to equip a number of F-15C fighters with Patriot Advanced Capability (PAC) 3 missiles. PAC-3 is a surface-to-air missile capable of intercepting a range of targets from conventional aircraft and cruise missiles to incoming ballistic missiles. PAC-3 is virtually a complete redesign of the earlier PAC-1/2 weapons and it is significantly better in most respects. However, the range of PAC-3 is limited to about 12 miles (19.3km) and the maximum ceiling is approximately 60,000ft (18,300m). The missile has a length of 17ft 1in (5.2m) and a weight of 700 lb (317.5kg), making it lighter than the AIM-54 Phoenix AAM developed for the US Navy's Grumman F-14 and the MIM-23B Hawk surface-to-air missile which has been adapted for use with F-14s by the Iranians.

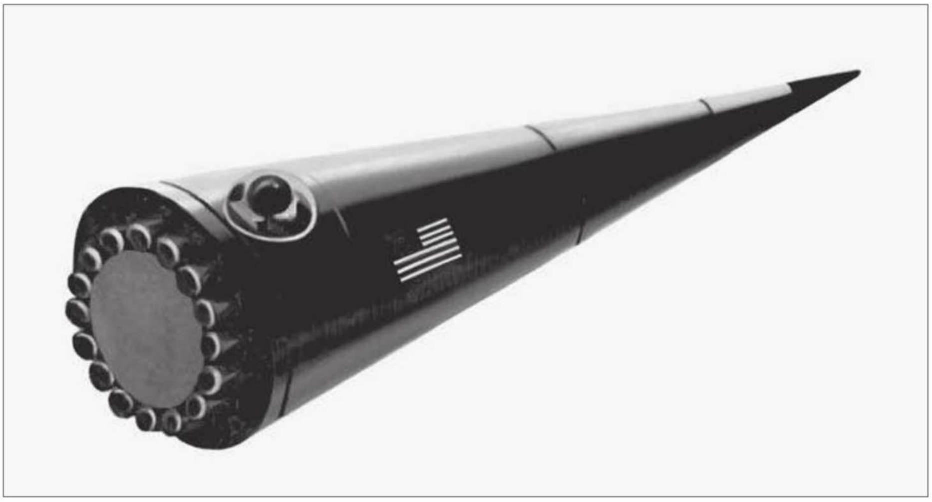
Lockheed-Martin received a $3 million contract from the US Missile Defense Agency to study the possibility of equipping F-15C fighters with these weapons, and the ability to destroy ballistic missiles during their boost phase using aircraft will considerably enhance US air defence capabilities. Although this is a very different weapon from the ASM-135A, using PAC-3 as an air-launched missile may be extended to other American combat aircraft such as the F-18, F-22 and F-35.

Space Cruiser

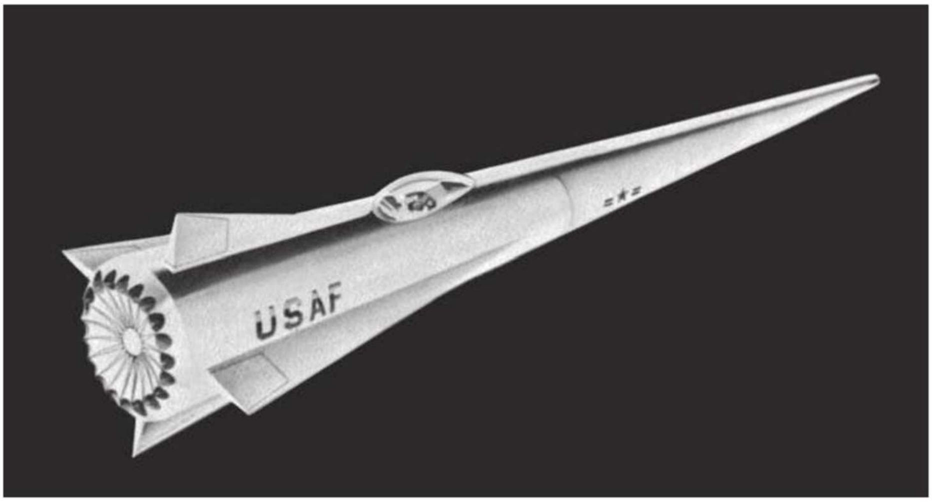
In 1960 the US Navy began a top-secret study called Early Spring to determine if it was possible to use a modified Polaris missile as an ASAT weapon. A Polaris submarine stationed beneath the orbital track of an enemy spacecraft would be used to launch a small vehicle on an intercept course. Having reached the general area of the satellite, this would then loiter while the target data was refined. Eventually the vehicle would close onto the satellite and a fragmentation warhead would be detonated by proximity fuse. Multiple rocket launches were considered feasible in the initial study, which was presented to a Congressional Committee in March 1961. Development continued for the remainder of the decade with several different proposals emerging from these studies, although most of the documentation relating to Early Spring remains classified or at least inaccessible. By the late 1970s Early Spring had been replaced by a more ambitious project called the Space Cruiser, which was closely modelled on the conical shape of a Poseidon ICBM re-entry vehicle.

The originator of this unusual design was Fred Whitney Redding Jr who worked as a consultant engineer for SRI International, and the project was sponsored by the Defense Advanced Research Projects Agency (DARPA) and the USAF. The main defence contractor chosen for development was Northrop, with support from the Sandia National Laboratories, who undertook wind tunnel testing of small models. The Navy wanted the ability to inspect and destroy Soviet spacecraft and considered a manned vehicle best suited to this role. The Space Cruiser would carry a single pilot (wearing a space suit) in a very rudimentary un-pressurised cockpit. The vehicle would be the minimum size required for all of the proposed missions and the specifications remained fairly constant as the design evolved. Overall length was 26ft 6in (8.077m), the mass was established at 9,920 lb (4,499kg) and in orbit the minimum delta v was 2,500ft/sec (762m/sec).

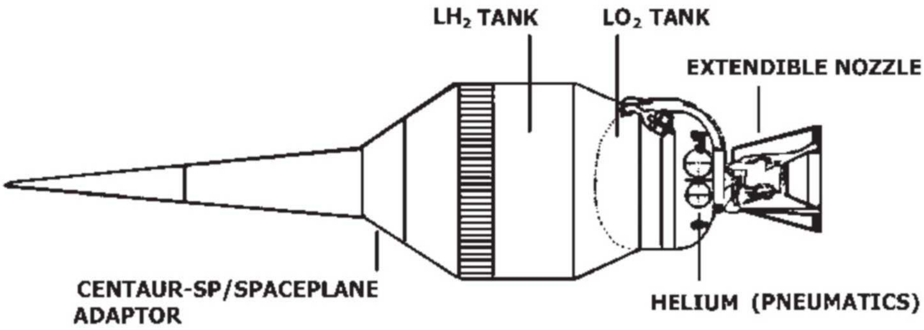
Most of the US Navy's anticipated missions could be achieved in one or two orbits and it was planned to make totally deniable



One of several configurations proposed for the Space Cruiser, which was a small manned vehicle designed to inspect Soviet satellites and destroy them. DARPA



An alternative Space Cruiser configuration, which was initially intended for covert deniable missions. USAF



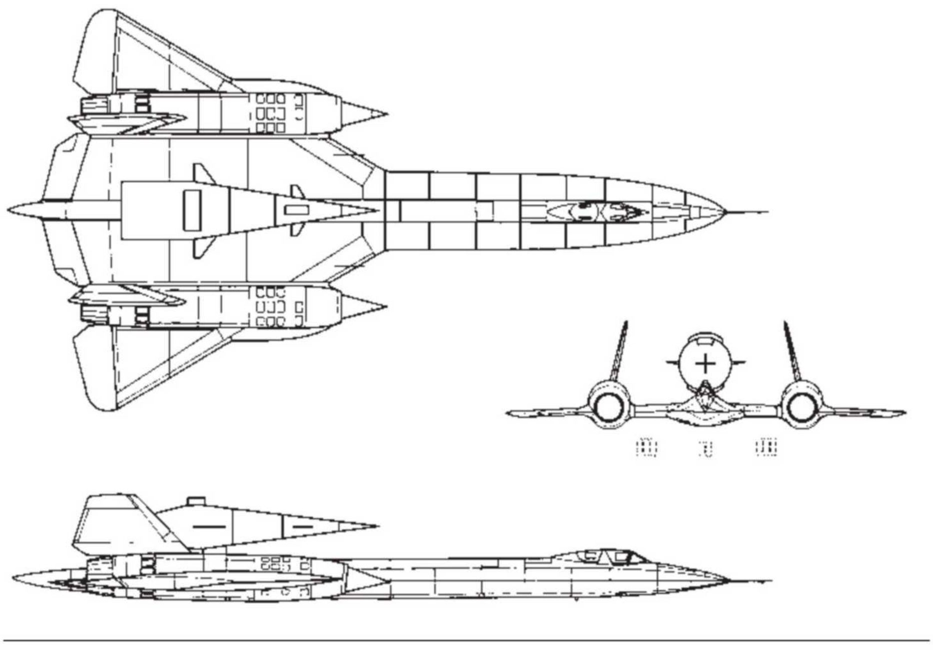
It was proposed to carry one or more Space Cruisers within the Space Shuttle's payload bay. The capability of this small vehicle would be considerable when a Centaur SP Orbiter module was attached. USAF

launches from submarines in remote locations using a Poseidon missile as a booster. It was intended to carry one or more Space Cruisers in launch tubes alongside Poseidon boosters and attach the upper stage at the launch location using a hoist system. Careful timing would allow the interception, inspection and probable destruction of Soviet orbital vehicles monitoring US warships, hopefully without the knowledge of the Russian space-tracking network. However, surface launches presented many problems and the submarine would have required extensive modification, and this led to the idea being abandoned. At this point the USAF began to take a more active interest in the Space Cruiser, suggesting the possibility of using a three-stage MX Peacekeeper ICBM to launch the spacecraft from a land site, or alternatively air-launching using a three-stage booster carried beneath a modified Boeing 747-200F.

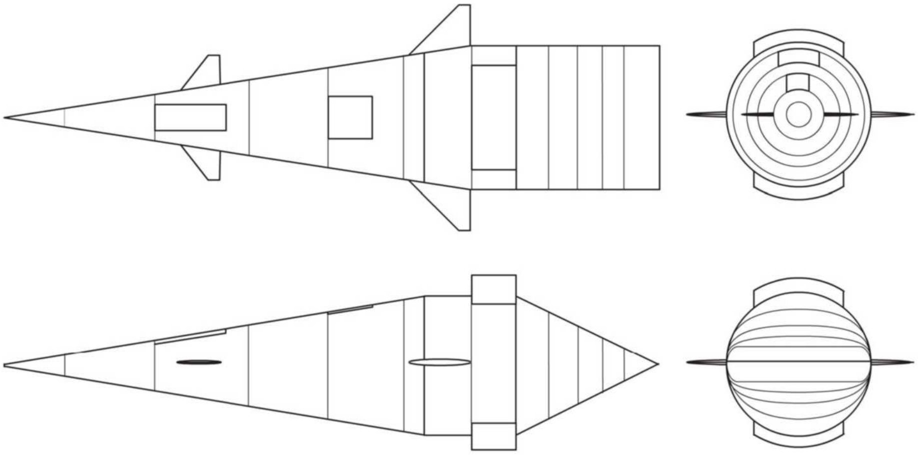
Many revisions to the internal layout followed with the pilot being moved to different positions as payload bays were re-located and different propulsion units were considered. A single liquid-fuelled bell nozzle rocket engine was finally dropped in favour of a compact but more complex plug cluster design produced by Aerojet which offered superior throttling. The fuel would be storable nitrogen tetroxide and monomethyl hydrazine. The Space Cruiser would also be equipped with a reaction control system for manoeuvring. No hydraulic systems would be carried and all operations would be electrically powered. The USAF wanted a small manned vehicle for the same reasons as the Navy, but it also envisaged missions with spacecraft carried into orbit by the Space Shuttle. The USAF version could also be equipped with a Centaur SP orbiter module providing a maximum delta v of 8,075ft/sec (2,461m/sec). A Space Shuttle would be able to carry as many as four fully-fuelled Space Cruisers within its cargo bay and these would be able to reach very high orbits occupied by geosynchronous (GEO) satellites.

Missions could last for a maximum of twenty-four hours and it was suggested that the Space Cruiser could make inspections of satellites suspected of carrying nuclear material (such as nuclear warheads) by close-range scanning for X-ray and low energy gamma ray emission. Other missions might involve ELINT or specialised photo reconnaissance operations. The USAF also considered a two-man vehicle, a fully automated variant and the possibility of using a Space Cruiser for rescue missions.

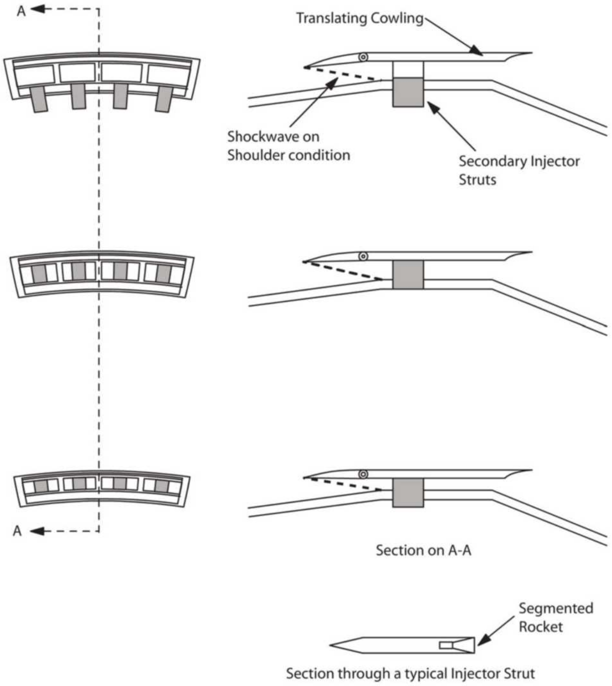
Once a mission was concluded the Space Cruiser would return to the Shuttle or make an independent re-entry. Limited aerodynamic control would be provided by movable flaps at the end of strakes towards the rear of the vehicle and a small air brake would be fitted. Having slowed sufficiently, a parafoil would be deployed from the Space Cruiser's centre of gravity and a controlled glide landing made. No form of undercarriage was contemplated so the spacecraft would not be able to land on a hard runway. On the other hand no damage was contemplated and the Space Cruiser would (theoretically) be reusable for between fifty and a hundred missions. To maintain project funding the USAF emphasised the research potential of the Space Cruiser to the politicians, often drawing parallels with the X-15. It claimed that the Space Cruiser was a logical extension to the Space Shuttle, capable of undertaking satellite repairs in high orbits and conducting experiments such as aerobraking on the edge of the atmosphere, which was a technique attracting increasing interest for future manned and unmanned applications. It was further suggested that the Space Cruiser's endurance could be extended beyond twenty-four hours which would allow operations to take place as far out as the Moon's orbit.



The initial version of the ALCV attached to an SR-71A. Although there were serious problems launching D-21 drones from earlier versions of the SR-71, which culminated in a fatal accident on 30th July 1966, by the end of the following decade it was felt that these issues had been addressed. The SR-71A had also been considered as a launch platform for a hypersonic D-21 replacement and a scale-sized X-24C test article. Bill Rose



Initial test version of the ALCV powered by a Rocket-Based Combined-Cycle (RBCC) propulsion module and intended for launch at supersonic speed from an SR-71A. Chris Gibson

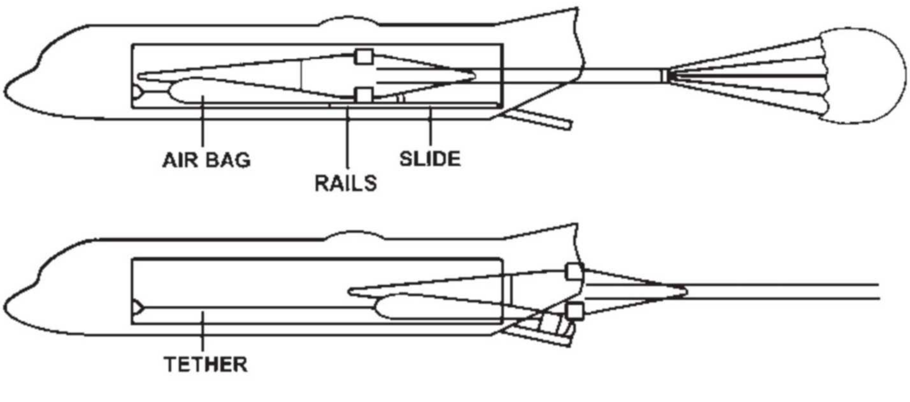

A
Translating Cowling
Shockwave on Shoulder condition
Secondary Injector Struts
A
Section on A-A
Segmented Rocket
Section through a typical Injector Strut

Mach = 2.5 Condition
Inlet lip pivots to maintain shock position. Only Primary injectors in use, with secondary injector struts retracted.

Mach = 5 Condition
Inlet lip positioned to maintain shock position. Secondary injector struts in place.

Mach = 10 Condition
Shock maintained by lip position, but entire cowling has translated to maintain air flow and using primary and secondary injection struts.

A new system of propulsion was proposed for the ALCV utilising a Rocket-Based Combined-Cycle (RBCC) engine conceived in the 1990s and sometimes referred to as the Strutjet. This advanced system combines the high specific impulse of a ramjet and the high thrust to weight ratio of a rocket in a single integrated propulsion unit. The illustration shows the basic principles of the RBCC and how the engine's cowling is configured for different performance conditions. Small rocket chambers are embedded in the trailing edges of inlet compression struts. Chris Gibson



The most favoured proposal for air-launching the ALCV/X-1S spacecraft was from an adapted C-130 transporter. The vehicle would be extracted from the cargo bay using a deployed parachute and an inflated air bag would ensure there was no contact between the two vehicles. Immediately after extraction the parachute would be jettisoned and the ALCV's propulsion system ignited. Bill Rose

Although the Space Cruiser was largely abandoned as a military system by the mid-1980s, development studies continued at a low level into the 1990s when new propulsive technologies revitalised the programme. The Space Cruiser was now a more sophisticated design called the Air Launched Cruise Vehicle (ALCV), also sometimes referred to as the X-1S. The first test version of the ALCV would be built without the plug cluster rocket engine and was to be powered by an experimental air-breathing ramjet/scramjet/rocket engine and fuel module, known as the Rocket-Based Combined-Cycle (RBCC) propulsion unit. As a high-altitude research aircraft the first prototype ALCV would be launched at supersonic speed from the back of an SR-71 aircraft in a similar manner to the D-21 drone from the 1960s.

When the SR-71A reached an approximate speed of Mach 2.5 and an altitude of about 70,000ft (21,300m), the ALCV's propulsion system would be started while the SR-71 would accelerate and climb until it reached Mach 3 at 80,000ft (24,400m). To help complete a clean separation from the SR-71 the ALCV would be equipped with small movable wings in a canard configuration. To remove weight, drag and any effects on the air-breathing engine system, it was anticipated that the wings might be jettisoned as the vehicle began to accelerate. If it was being utilised as a manned vehicle the ALCV would be equipped with an escape capsule and would land using a parafoil wing and no undercarriage.

Assuming these test fights went well, a more advanced one or two-man ALCV capable of reaching orbit would be built. The most favoured method of air-launching this vehicle was to extract it from the cargo bay of a modified Lockheed C-130J transport aircraft. The proposed propulsion module would be a more powerful RBCC engine based on the advanced Aerojet Strutjet system that would separate from the ALCV once its fuel supply was exhausted; the engine module would be recoverable.

It was hoped to attract renewed interest from the military, although the emphasis was on low cost civil operations and the ability to service and repair satellites. There were suggestions that a fully pressurised version of the Space Cruiser called the Lifecraft might be used as an emergency escape vehicle for the ISS and as a rescue vehicle. Another possibility that received serious consideration was the use of Space Shuttle External Tanks for pressurised hangars for Space Cruisers based at the ISS. The tanks jettisoned from the Shuttle would be recovered by a two-man Cruiser and towed up to the space station's orbit where they would be adapted for re-use. Development of RBCC engine technology has continued, but the ALCV failed to attract any further interest.

The Military Shuttle

In April 1969 NASA formed the Shuttle Task Group to develop a reusable spacecraft called the Orbiter. The basic requirement was for a craft capable of reaching a 300-mile (482km) high orbit which on return to Earth would land like a conventional aircraft. Every major defence contractor participated in the study and a wide variety of designs were produced from spaceplanes launched by massive booster rockets to cutting edge SSTO concepts. Although NASA and the USAF narrowed the choice to a fully re-usable two-stage system, financial limitations and political considerations led to the adoption of a spaceplane with a large disposable fuel tank and two re-usable solid fuel boosters.

The main contractor selected to build the Shuttle Orbiter was North American Rockwell and on 5th January 1972 President Nixon gave approval for the Shuttle programme, which was heavily promoted as the answer to NASA's manned spaceflight requirements for the remainder of the century. Although receiving less publicity, the Shuttle had been designed to carry military payloads which led to compromises that made the spacecraft less than ideal for either user. The initial DoD requirement was to launch classified satellites. The first mission was to take place in June 1982 and the Pentagon planned to steadily increase Shuttle usage. By the mid-1980s the USAF was preparing to begin military Shuttle launches from Vandenberg AFB (often called VandyLand by USAF personnel) in California, which had previously been chosen as a launch site for MOL. It was an important alternative to the Kennedy Space Center because high inclination polar orbits could be undertaken without concerns about dropping boosters or aborting launches over inhabited areas or foreign territory.

When the Challenger accident took place on 28th January 1986 the first Vandenberg Shuttle launch, designated STS-62A, was placed on indefinite hold. There were various unresolved problems with the SLC-6 facility at Vandenberg but this launch complex was largely complete and almost ready for use. SLC-6 had cost around $4 billion and work was nearing completion at Easter Island and Hao to extend existing runways for Transoceanic Abort Landing (TAL) requirements. The STS-62A mission was scheduled to carry a new highly classified surveillance satellite called Teal Ruby into orbit and this

NASA
United States
USA
Columbia
NO PARKING

The Space Shuttle Columbia. NASA

platform was designed to track aircraft and cruise missiles using infrared sensors. But the Challenger disaster meant that all further NASA Shuttle missions were cancelled and it was decided to shut down SCL-6 while the USAF decided what to do next. The facilities were then mothballed and the idea of making Shuttle launches from Vandenberg was completely abandoned in late 1986. Teal Ruby never reached orbit because, when it eventually became possible to undertake a launch, the satellite's technology was judged to have become obsolete. After Shuttle flights had resumed a further eight DoD payloads were placed in orbit, with the last mission taking place in 1992. In total eleven classified Shuttle missions had been undertaken and the payloads ranged from secure communications platforms to early warning and radar imaging satellites. Nevertheless, in the aftermath of the Challenger loss the USAF switched to using the Titan 34D launch vehicle which had been developed as a backup for the Shuttle.

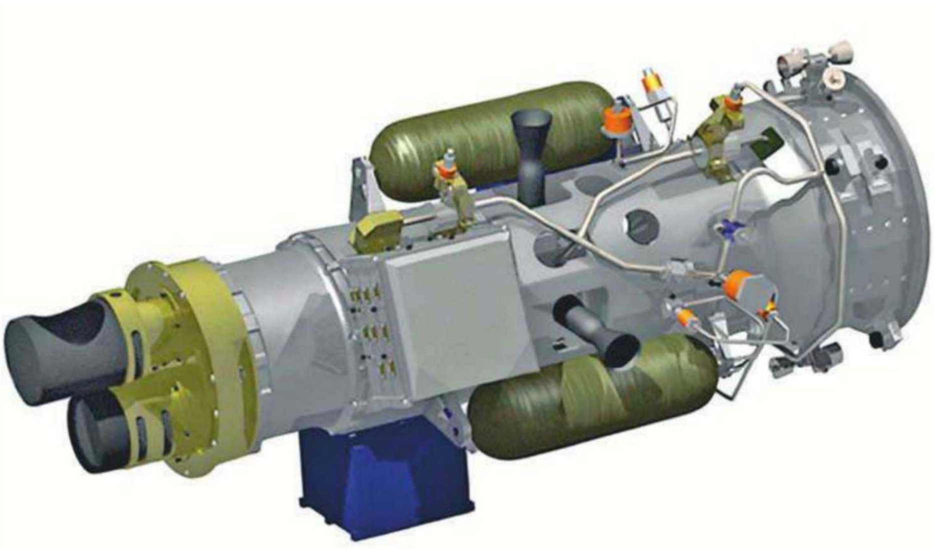
In addition to satellite launching, other military roles proposed for the Shuttle included satellite inspection, the occasional repair of US platforms and the disablement of foreign unmanned vehicles. During the 1980s there were suggestions made in Russia that America might use the Shuttle to snatch Soviet satellites and return them to Earth, although this was unrealistic as satellites are easy to booby-trap. It is also true that even making a close approach to any foreign satellite in peacetime might have serious consequences and the idea of covert interference with another nation's spacecraft raises all manner of difficult issues.

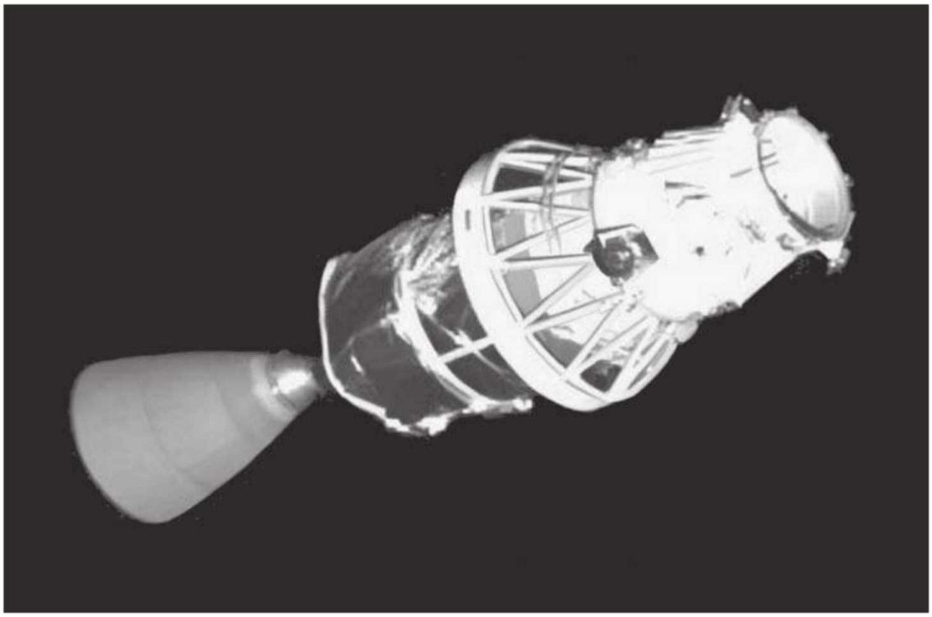
Whether or not the Shuttle was ever considered as a reconnaissance vehicle is unknown, although it would have been possible to carry an impressive range of optical and ELINT equipment in the cargo bay. But the increasing use of surveillance satellites, lengthy preparation time for a Shuttle mission and cost would seem to have ruled this out. The Shuttle has always been an easy target to track in space, making it vulnerable to ground-based Directed Energy Weapons (DEWS) and ASATs, although some countermeasures are said to have been considered. One possible use for the Shuttle would have been the covert deployment of orbital military payloads disguised as commercial satellites. These platforms could have been used to dispense small space mines or ASATs with stealthy features. They would have the ability to destroy enemy satellites by colliding with them, rendezvousing and exploding within a close proximity, or possibly attaching an explosive package for detonation at some future date.

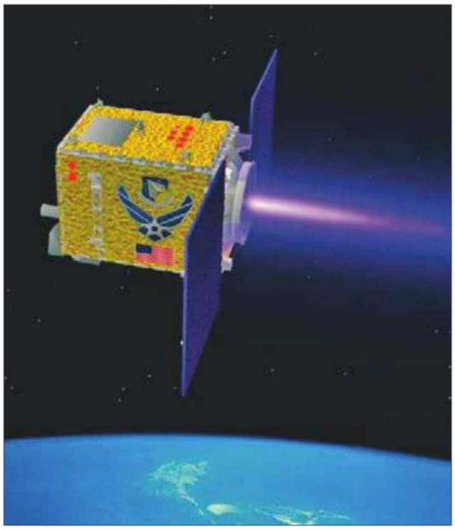
Very small satellites are nothing new. Many of the earliest designs were surprisingly small and would now be classed as microsatellites. The world's first satellite, Sputnik 1, had a diameter of 22.8in (579mm), the Sputnik-shaped American Vanguard 1 was a miniscule 6.4in (162.5mm) in diameter and the US

Top right: **One of the big disadvantages of the Space Shuttle as a military vehicle was/is the lengthy preparation time for each mission, the high cost and an inability to undertake operations in secret.** NASA

Right: **Shuttle Endeavour on the launch pad at the Kennedy Space Center.** NASA







The experimental XSS-10 microsatellite was deployed on 30th January 2003. USAF

The Delta 2 stage that placed the XSS-10 into orbit. This image was made on 30th January 2003 by the XSS-10 as it manoeuvred around the vehicle to relay data to ground controllers. USAF

Designed as the follow-on to the XSS-10, the slightly larger experimental XSS-11 microsatellite built by Lockheed Martin has been under consideration for development as an ASAT. USAF

Opposite page:

Artwork showing a demonstration TRW/Boeing space-based chemical laser proposed during a 1998 USAF-sponsored study. The Shuttle may have been considered as a means of deploying this type of weapon. USAF

The 'Rods From God' weapon concept that may have been considered for orbital deployment by the Space Shuttle. USAF

Navy's Nosnik was a mere 8in (203mm) in diameter. In late 1997 the Japanese launched a small satellite to test fully automated rendezvous and docking procedures. Known as the Experimental Test Satellite 7 (ETS-7), it comprised two spacecraft called 'Chaser' and 'Target' which completed several autonomous docking tests during 1998 and 1999. This was followed by a small cylindrical microsatellite designated Experimental Spacecraft System 10 (XSS-10) which had started life in the mid-1990s. Testing in space was originally scheduled to take place during a Shuttle flight but this became increasingly difficult to arrange.

The USAF finally launched XSS-10 in January 2003 as a secondary Delta 2 payload. The $100 million XSS-10 was built by Boeing and measured 33in (838mm) in length and 17in (432mm) in diameter and had a mass of 68 lb (31kg). XSS-10 was designed to operate for twenty-four hours with power being provided by newly developed lithium-polymer batteries. After release from the Delta 2's second stage on 30th January 2003, the XSS-10 moved away from the vehicle and began a series of manoeuvres around it, relaying information to ground controllers from its onboard camera.

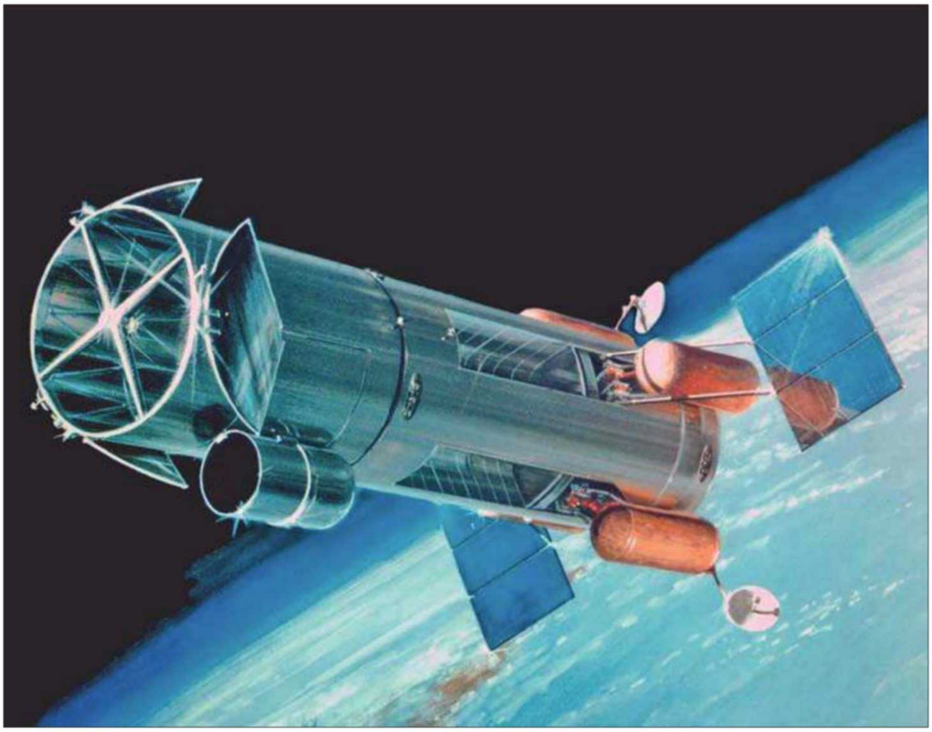
The follow-on slightly larger XSS-11 experimental microsatellite was built for the USAF by Lockheed-Martin using some systems that may be employed for a future Mars sample retrieval mission. While the emphasis with this project has been research, a senior Pentagon official acknowledged in December 2003 that this vehicle was being considered as a kinetic ASAT. It is equally likely that the XSS-11 utilised features required for a space-to-space missile.

A particularly interesting space weapon that appears to have been considered as a Shuttle payload was the expendable X-Ray laser. This was conceived during the 1970s at the Lawrence Livermore Laboratory under a black budget programme called Project Excalibur. The initial plan was to park substantial numbers of these weapons in orbit as a means of killing Soviet ICBMs during their boost phase and clearly there wasn't much concern about breaching the 1967 Outer Space Treaty if the technology proved viable. The Project Excalibur weapon would take the form of a small thermonuclear device surrounded by about twenty lasing rods made from an unspecified dense metal, quoted as being either 3ft (0.91m) or 8ft (2.4m) in length. Calculations suggested that the incredibly high discharge of energy produced just before the rods were destroyed could be directed into an intense beam of radiation.

Initially cancelled by the Carter Administration, the project was revived under Reagan's SDI programme when it was suggested that a single payload of these weapons deployed from the Shuttle's cargo bay could destroy the electronic systems of every Soviet ICBM stored in a hardened silo. It is believed that several Excalibur-related underground nuclear tests were conducted during the 1980s, but grave doubts began to surface about weaponising the technology. Some scientists claimed that Excalibur was decades away from realisation, while other insisted it was completely unworkable. With rapidly mounting costs and growing concerns over the feasibility of the project, it was finally deemed non-viable and scrapped.

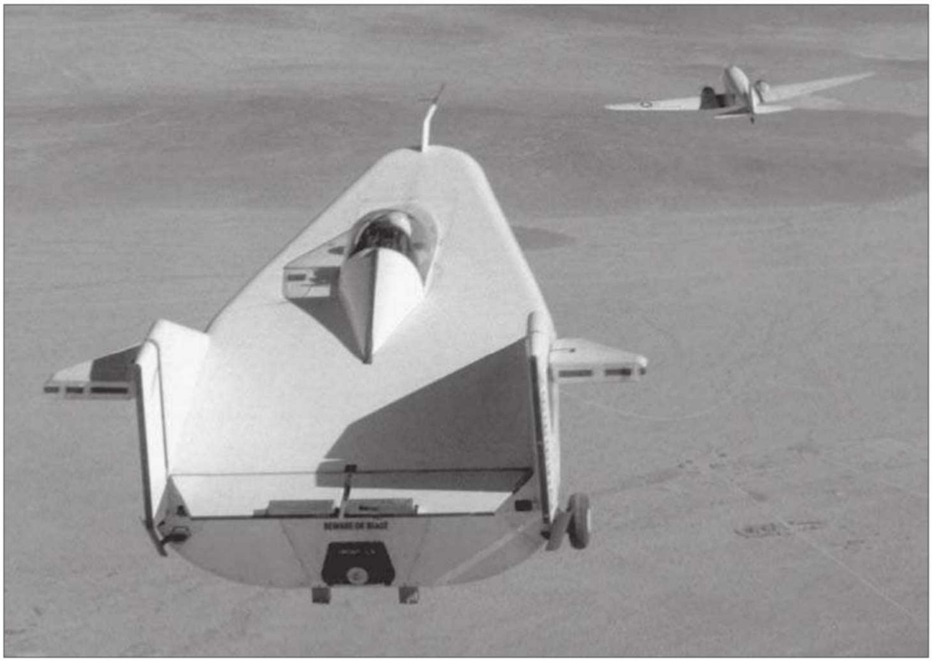
The Soviets certainly feared a pre-emptive strike from a Shuttle launched into a polar orbit from Vandenberg and it would have been feasible to carry nuclear space-to-ground weapons in the cargo hold. Space-to-ground weapons have been secretly studied for several decades and may have been tested. In basic form we can imagine a weapon being assembled from readily availably ICBM components, comprising several re-entry vehicles on a bus, a control and guidance module and a solid fuel rocket motor for de-orbit. It would be possible to carry a considerable number of these missiles into orbit aboard the Shuttle within its 60ft by 15ft (18.2m by 4.5m) cargo bay.

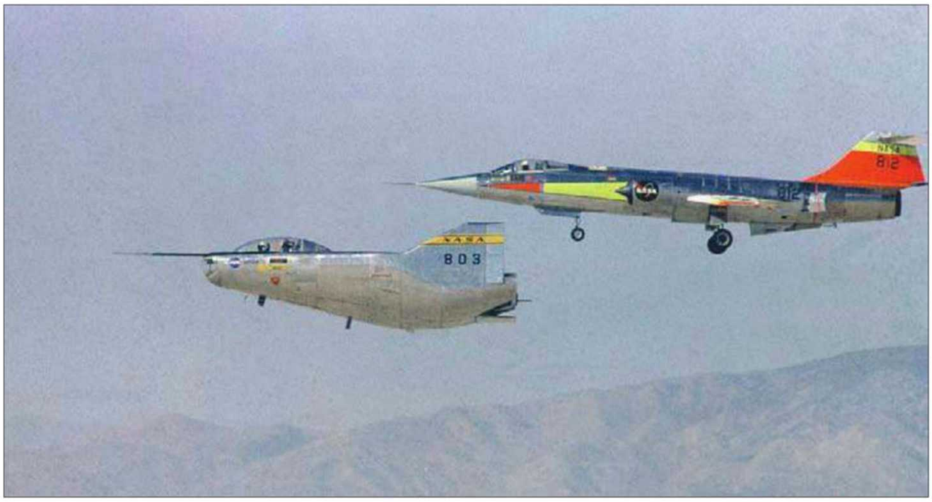
Another space-to-ground weapon that was examined for possible carriage by the Shuttle would utilise kinetic energy released during impact. Eugen Sänger made the earliest known proposal for a space-launched kinetic energy weapon during World War Two, and it is worth noting that this kind of system does not violate the 1967 Outer Space Treaty. The idea of using space-based kinetic energy weapons was considered by USAF scientists during the 1950s. Meteorites were studied as a starting point and this led to suggestions for aerodynamic projectiles made from a suitable metal, although the scientists concluded that such a system was unworkable at that time. A kinetic energy weapon is completely inert and has no chemical or nuclear explosive component, simply using its mass and hypervelocity impact to release substantial destructive force. More recent American studies have produced proposals for space-launched rod-shaped projectiles with approximate lengths of 39in (1m) to 20ft (6m) made from a dense, high melting point metal such as tungsten. Sometimes referred to as 'Rods From God', the larger projectiles would have the potential to release a massive amount of focused explosive energy, perhaps equalling the force of a small tactical nuclear weapon.

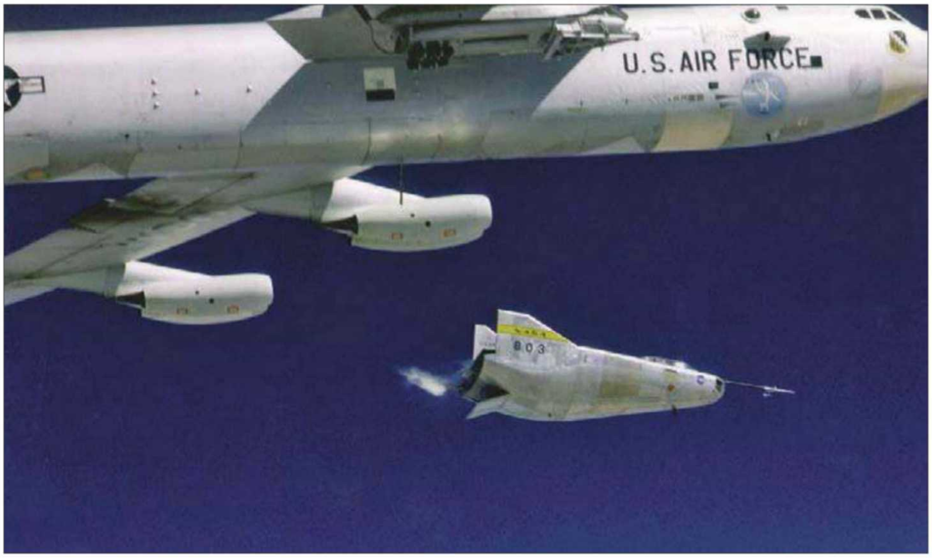


An orbital launch would be hard to detect and there would be no defence against this kind of attack. But delivering rods to surface locations with any degree of accuracy remains a major technical challenge. The rods are unsuitable for use against mobile or fast moving targets and lifting the required mass into orbit would be very expensive. Shuttle-deployed kinetic weapons would seem to have been the subject of several classified studies during the 1980s, but nothing came of this work and we are unlikely to see space-based kinetic energy weapons developed in the near future. However, the development of kinetic energy weapons for use within the atmosphere has continued and a US Navy/USAF hypersonic missile called HyStrike (High-Speed Strike Missile) is now undergoing development. This affordable missile will cruise to its target (typically a subterranean facility) at Mach 4 and have a maximum range of about 750 miles (1,200km). HyStrike then accelerates to hypersonic speed before slamming into the target, which will release enough energy to destroy the majority of deeply buried bunkers and underground installations.

To briefly summarise on the Shuttle as a military space system it seemed doomed to failure from the outset. Reliability and operational costs have been major ongoing issues and it remains possible that a deep black alternative was developed for the USAF in the wake of the first Shuttle loss.







Lifting Bodies

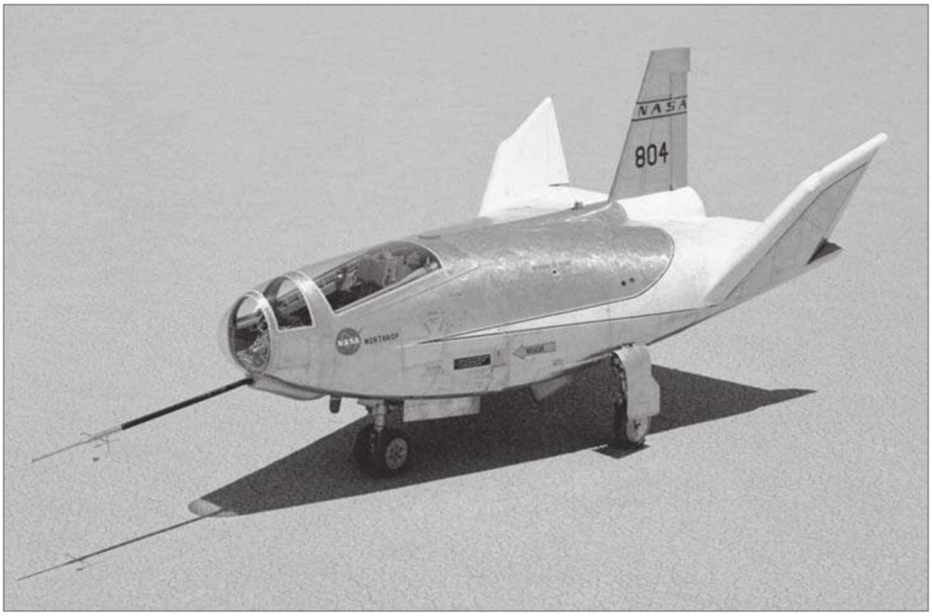
During the early 1950s work on high-speed flight undertaken by Alfred Eggers and H Julian Allan at NACA Ames (later NASA Ames) determined that a re-entry vehicle with a suitable shape might be able to manoeuvre at hypersonic speeds. This led to the lifting body configuration which was initially favoured for the Apollo Lunar Project's spacecraft but finally lost out to a much simpler ballistic capsule design. The USAF was now examining the lifting body for manned spacecraft and missile re-entry vehicles, but it was a group of engineers at NASA Dryden who generated widespread interest in 1962 when they proposed the development of a simple low-cost lifting body experimental aircraft. Their inexpensive one-man prototype had an overall length of 20ft (6.1m), a span of 14ft 2in (4.32m) and no propulsion system. It quickly received management approval and was built from simple cheap materials that included steel tubing and plywood. Some help was obtained from the Briegleb Glider Company and the aircraft was ready for testing by mid-1963. This unusual looking wingless design received the official designation M2-F1 (Manned 2-Flight 1) and early tests at Rogers Dry Lake were made by towing the prototype behind a Pontiac Catalina convertible car (modified by Bill Straup) at speeds of up to 120mph (190km/h). The Pontiac was soon replaced by a C-47 aircraft behind which NASA Test Pilot Milt Thompson was towed to an altitude of 12,000ft (3,660m) before making a series of surprisingly well controlled landings.

In 1965 the success of the M2-F1 encouraged NASA to contract Northrop to build two advanced follow-on rocket powered lifting body research aircraft, designated M2-F2 and HL-10, at a total cost of $1.8 million. The 22ft (6.7m) long M2-F2 made its first captive flight under a modified Boeing B-52 bomber (which was also used for X-15 trials) in March 1966 and its first glide flight in July 1966. Unfortunately, the test programme ran into

The experimental M2-F1 lifting body being towed behind a C-47 at the Flight Research Center (later Dryden Flight Research Center) at Edwards AFB, California. NASA

Escorted by an F-104 chase plane, the M2-F2 lifting body makes a demanding un-powered landing during trials in the mid-1960s. NASA

Although seriously damaged during a landing accident on 10th May 1967, the M2-F2 was salvaged and re-built as the M2-F3, which differed in some minor detail and utilised a third central tailfin. Test flights began in 1970 and lasted until the end of 1972. NASA



NASA's experimental HL-10 lifting body aircraft began flight tests in late 1966. NASA

Rear view of the Northrop HL-10 lifting body research vehicle. NASA

serious problems on 10th May 1967 when NASA test pilot Bruce Peterson made a spectacular lakebed crash landing in which he was seriously injured. The footage of this event was so dramatic that it ended up being used during the opening title sequence of the popular 1970s sci-fi TV series *The Six Million Dollar Man*.

Although seriously damaged, Northrop rebuilt the M2-F2 into a new vehicle that was called the M2-F3, which differed from the earlier model in having a third central tailfin to improve stability. Test flights began in 1970 and the first powered flight took place at the end of the year. Trials lasted until the end of 1972 and during that period the M2-F3 reached a maximum speed of Mach 1.6 and climbed to an altitude of 71,500ft (21,793m).

The one-man Northrop Horizontal Landing – NASA Langley Design #10 (HL-10) was developed specifically to test safe landing techniques applied to a vehicle configured for re-entry. Dimensions were similar to the other lifting body test aircraft with a length of 21ft 2in (6.45m) and a span of 13ft 7in (4.15m), providing an effective wing area of 160ft^2 (14.9m^2). Maximum launch weight was 6,000 lb (2,721kg) and the HL-10 used a Reaction Motors XLR-11 four-chamber rocket engine producing 8,000 lb (35.7kN) thrust (which was chosen for all the powered NASA lifting body vehicles). The HL-10 was built from many off-the-shelf components including a landing gear normally fitted to a Northrop T-38A Talon trainer and an ejector seat taken from a surplus F-106A. HL-10 made its first airdrop from a B-52 on 22nd December 1966 and this was followed by ten further unpowered flights. Releases would normally take place at 45,000ft (13,716m) and a speed of about 450mph (724km/h). Thirty-seven test-flights were made and on one occasion the HL-10 reached a maximum speed of Mach 1.8 and during a subsequent flight it climbed to an altitude of 90,030ft (27,441m). Landings required a special and quite dramatic technique with the undercarriage only being lowered at the final moment before touchdown because of the drag it created. Nevertheless, the HL-10 was said to be the best handling of all the lifting bodies flown by NASA and its last flight took place on 17th July 1970.

During the mid-1970s a proposal to fly the HL-10 in space was made by NASA engineer R Dale Reed. He suggested heavily modifying the HL-10 with heat shielding, a reaction control system and various other alterations. Launching the vehicle would be achieved using a Saturn V rocket left over from the cancelled Moon programme. The HL-10 would be attached to an Apollo capsule, occupying the same position as the Lunar Module during a Moon mission. Once in orbit, a robotic arm would be used to detach the HL-10 and bring it alongside the capsule. An astronaut would then leave the Apollo spacecraft and make a short spacewalk to the HL-10. A full series of system checks would be performed for a flight back to Earth from within the HL-10's cockpit, but the astronaut would finally return to the Apollo capsule. The unmanned HL-10 would then be de-orbited and fly back to base under remote control. If everything went according to plan, a second mission would involve a manned re-entry and return to Edwards AFB. Apparently Wernher von Braun was a strong supporter of Reed's idea but senior NASA officials did not share his enthusiasm and the plan was rejected. For many years there have been rumours that a USAF black budget development of the HL-10 was secretly built and has been flown in space. After considerable research I can find no evidence to support this possibility – in fact just concealing the launch of such a vehicle would be virtually impossible.

From the outset there was USAF interest in the NASA lifting body programme and, although the ability to inspect and destroy satellites was being considered for the X-20, an alternative study for a manned lifting body spacecraft with this capability was secretly commissioned. This project followed the earlier ASAT programme called SAINT and was handled by the USAF's Space Systems Division, receiving the name SAINT-II in 1961. The proposed two-man lifting body SAINT-II vehicle would be launched by a Titan II rocket fitted with a Chariot LF2/Hydrazine third stage. Some systems developed during the earlier SAINT programme would find their way into this manned spacecraft, which would be capable of operating in high orbits if required. It was anticipated that the first test flight could be made in 1964 and the USAF believed that SAINT-II had a greater capability than the X-20. Nevertheless, there was sustained opposition from supporters of the X-20 who regarded SAINT-II as a serious threat and in late 1962 the SAINT-II combat spacecraft was cancelled.

Alongside SAINT-II the USAF was running an important classified aerodynamic programme at the Flight Dynamics Laboratory (FDL), located at Wright-Patterson AFB, which had started in late 1959. FDL scientists were examining ideas for high-performance manned aerospace vehicles to follow the X-15, although the underlying USAF interest in lifting bodies was the production of a new manoeuvrable ICBM warhead. This was to be capable of defeating future Soviet missile defence systems and film return capsules launched from spy satellites. Because of this the focus of attention was on small vehicles that would initially be used to obtain data on the effects of high thermal loads produced at hypersonic

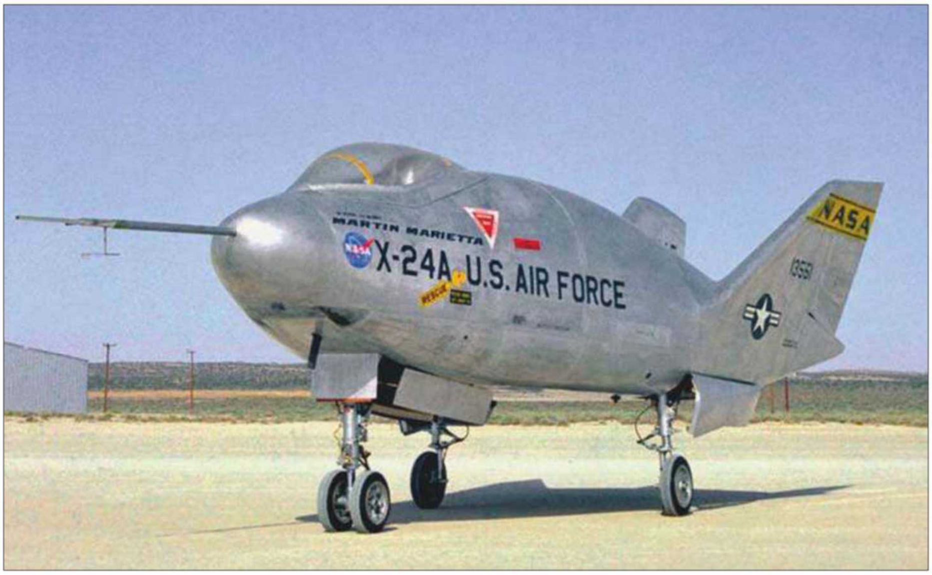
Far left: **ASSET 1 mounted on a Thor DSV-2F rocket is prepared for launch at Cape Canaveral during the autumn of 1963.** USAF

Left: **The third compact ASSET re-entry test vehicle, which was recovered near Ascension Island in 1964 and is now a museum exhibit.** USAF

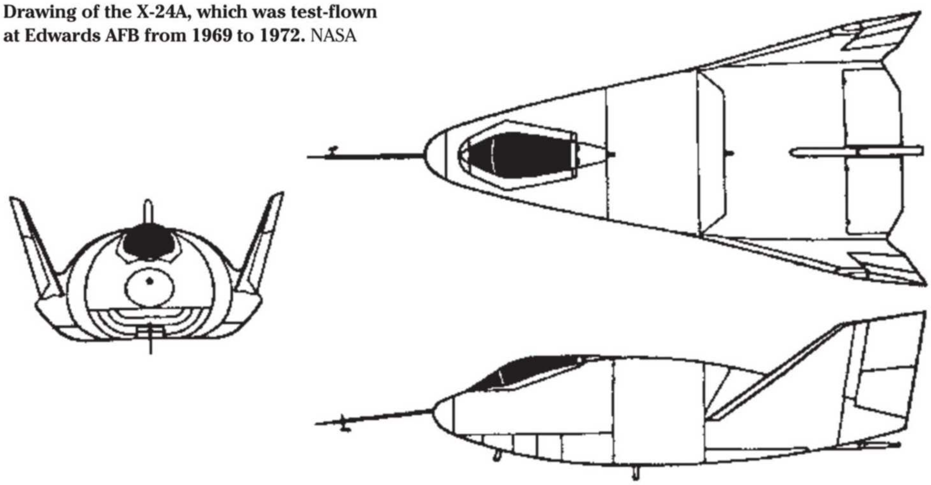
McDONNELL
ASSET
USAF
RTD

Lower left: **ASSET re-entry test vehicle being prepared for launch.** USAF

Below: **Built by Martin Marietta, the X-23A Prime was a small rocket-launched lifting body hypersonic test vehicle.** USAF



The Martin X-24A lifting body research aircraft built for NASA and the USAF. After a long development period it was delivered to Edwards AFB and made its first air-drop glide test on 17th April 1969. NASA



Drawing of the X-24A, which was test-flown at Edwards AFB from 1969 to 1972. NASA

speeds. The name of this programme was Aerothermodynamic/elastic Structural Systems Environmental Tests or ASSET.

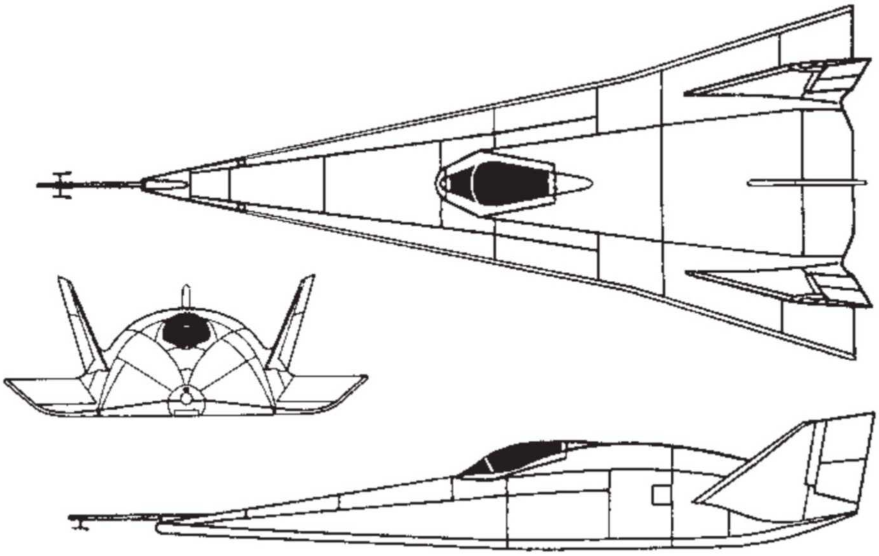
Charles Cosenza headed this specialised project, with support coming from the McDonnell Aircraft Corp who received a contract in 1961 to construct an initial ASSET craft. The McDonnell ASSET was little more than a compact instrument-carrying re-entry vehicle. It had an overall length of 5ft 9in (1.75m), a span of 5ft (1.52m) and a mass of 1,190 lb (540kg). The undersurface was flat and covered with panels made from columbium and molybdenum, which were able to withstand temperatures as high as 3,000°F (1,649°C). The nose was made from zirconium and capable of handling temperatures as high as 4,000°F (2,204°C). Launches of these test vehicles began in autumn 1963 and took place at Pad 17B, Cape Canaveral using Thor and Thor-Delta rockets. Six tests were completed and the programme lasted until early 1965.

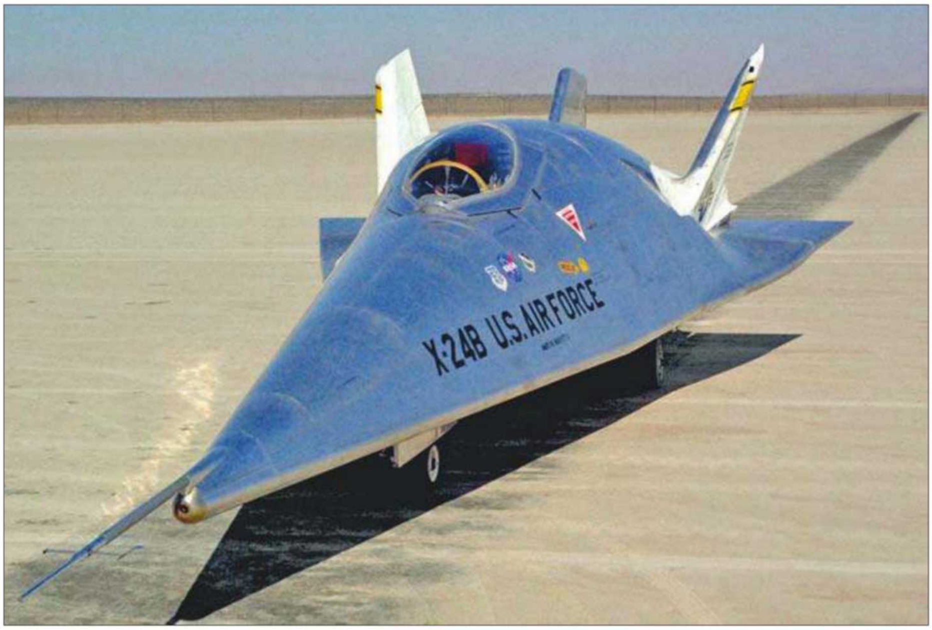
Each launch would lift an ASSET to an altitude of about 200,000ft (61,000m), where it would begin a long hypersonic glide of about 2,500 miles (4,000km) while onboard instruments relayed details of the vehicle's condition to flight controllers. Only the third ASSET test vehicle was recovered near Ascension Island in 1964 and ASV-3 eventually became a USAF museum exhibit. There is evidence that a study was undertaken to examine the possibility of building a Gemini capsule in the ASSET lifting body configuration. Operated by the USAF, this would have been capable of making horizontal runway landings using skids, but nothing came of the idea.

ASSET led to a further research project called Precision Recovery Including Manoeuvring Entry (PRIME), which utilised a series of small lifting bodies built by Martin Marietta and designated X-23A/SV-5D. The contract to build these vehicles was issued by the USAF in 1964 and each of them had an overall length of 6ft 9in (2.05m), a span of 3ft 10in (1.16m) and a height of 2ft 1in (634mm). The hypersonic lift/drag Ratio was 1:1. The X-23A was constructed from a variety of available aerospace materials including titanium, beryllium and aluminium alloys and stainless steel. The nose cone was covered with a carbon-phenolic resin and the outer skin was coated with an ablative heat shield of varying thickness developed by Martin Marietta.

A parachute system was contained in a bay located at the X-23A's centre of gravity which comprised a drogue ballute to deploy at supersonic speed and a parachute opening out to 47ft (16.32m). The X-23A would then be snatched in mid-air by an adapted JC-130B Hercules transporter, assuming everything went according to plan. The X-23A had more of a teardrop shape than the ASSET ASV-3 design and was fitted with two upright fins. An adapted Atlas ICBM was chosen as the launch vehicle because this would be able to reach a higher speed and altitude than the Thor Delta. While the ASSET vehicles had been used to test heat resistant materials, the X-23A was designed to explore cross-range manoeuvring as great as 710 miles (1,142km), which would be handled by a compact hydrogen peroxide reaction control system and small flaps.

The first test launch of an X-23A took place at Vandenberg AFB on 21st December 1966 and the vehicle was carried to an apogee of 900 miles (1,448km) by an Atlas rocket. This was a simple trial flight and cross-range testing was not attempted. Useful telemetry was provided but the mid-air retrieval was unsuccessful and so the first X-23A was lost. The second example was launched from Vandenberg on 5th March 1967 and achieved a successful 655-mile (1,055km) cross-range manoeuvre, but the retrieval operation again failed. The third test on 20th April 1967 proved the most successful and, besides demonstrating a 711-mile (1,145km) cross-range capability, this X-23A was retrieved 5 miles (8km) from the target area near Kwajalein. Having achieved all of its objectives, the development team cancelled two further planned launches and the project was concluded. The third X-23A eventually passed to the USAF museum at Wright-Patterson AFB where it is currently on display.





In 1972 the X-24A was returned to Martin for a complete re-build. This resulted in a significantly different aircraft that was re-named X-24B. NASA

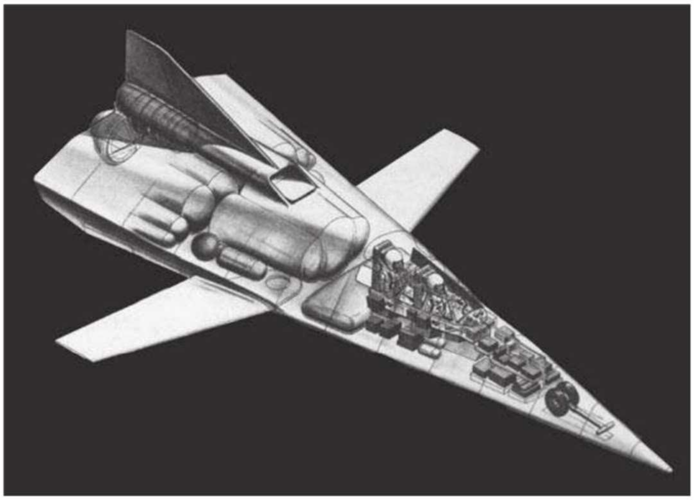
Largely a product of tests undertaken by the USAF Flight Dynamics Laboratory, the experimental X-24B drew heavily on a hypersonic configuration called FDL-7. NASA

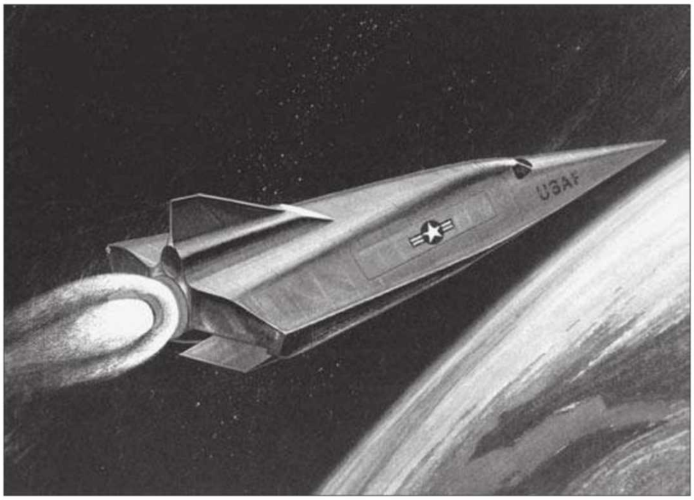
In 1962 the USAF became directly involved with NASA's lifting body programme when it agreed to partly fund a new experimental aircraft as part of its Piloted Lifting-Body Tests (PILOT) project. The new aircraft was designated X-24A and Martin Marietta was contracted to build one rocket-powered version (serial 13551). Two further jet-powered examples (SV-5J) were built but never flown. The one-man teardrop-shaped X-24A had a length of 24ft 6in (7.46m), a span of 11ft 6in (3.5m), a height of 9ft 6in (2.89m) and a wing area of 195ft^2 (18.1m^2). Maximum launch weight was 11,447 lb (5,192kg) with propulsion being provided by one Reaction Motors XLR-11 four-chamber rocket engine producing 8,480 lb (37.72kN) of thrust. The forward located pressurised cockpit was fitted with a zero-zero ejection seat and conventional flight controls were used. X-24A was equipped with a tricycle undercarriage using components designed for the Northrop T-38 Talon and North American T-39 Sabreliner.

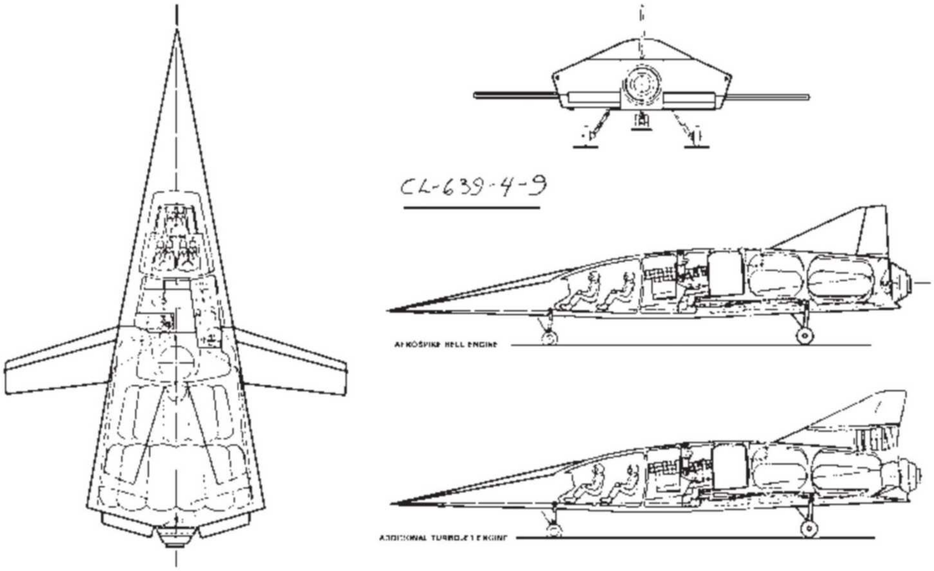
After a lengthy development period the X-24A was delivered to Edwards AFB and made its first unpowered air drop test flight on 17th April 1969 with USAF Major Jerauld Gentry at the controls. The first powered flight took place in March 1970 and a total of twenty-eight missions were flown. The highest speed achieved by the X-24A was Mach 1.6 and on one occasion it reached an altitude of 71,400ft (21.76m). Using a rocket engine which was similar to the unit that powered the first Bell X-1A, the X-24A was almost 200mph (321km/h) faster at the same level of thrust. It is believed that the some of the SAINT-II designs shared similarities with the X-24A, and many years later the X-24A was used as a starting point for the X-38 Crew Return Vehicle (CRV). This was primarily intended for emergency use for the ISS, but finally lost out to readily available and less expensive Russian capsules. In 1972 the X-24A was returned to Martin's facility at Denver for a very extensive re-build, which produced an almost entirely new aircraft.

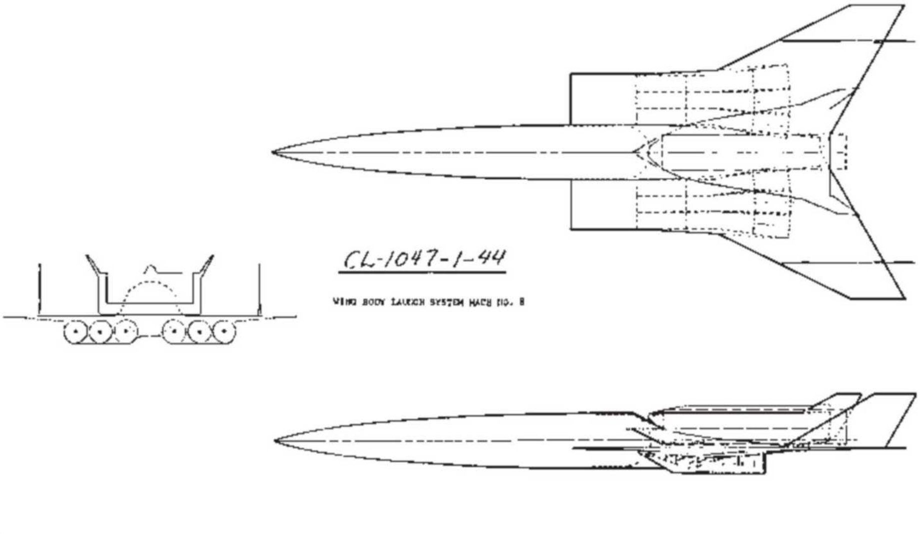
Designated X-24B this flatiron shape was expected to be more stable and somewhat easier to fly. The aerodynamic shape had been produced from exhaustive studies undertaken at the USAF Flight Dynamics Laboratory, who arrived at a highly swept double delta with a completely flat underside and a rounded upper fuselage. This was an adaptation of a hypersonic configuration the Laboratory called FDL-7, which soon became FDL-8. The new aircraft looked little like the X-24A and had an extended nose to give an overall length of 37ft 6in (11.43m). The span was increased to 19ft (5.79m) but the height remained the same as the X-24A; wing area was 330ft^2 (30.7m^2). Maximum launch weight rose to 13,800 lb (6,259kg) and the rocket engine was unchanged. After the return of the re-built test vehicle to Edwards AFB, NASA Test Pilot John Manke made the first glide flight from a B-52 on 1st August 1973 and also the first powered flight on 15th November 1973. The X-24B flew until November 1975, completing thirty-six flights of which twelve were un-powered. The aircraft attained a maximum speed of Mach 1.76 and reached a maximum altitude of 74,130ft (22.59km). The X-24B showed that it was possible for an aircraft with this particular configuration to make controlled unpowered landings and NASA would come to regard these trials as an essential step in the Space Shuttle's development. This aircraft is now an exhibit at the National Museum of the USAF at Wright-Patterson AFB in Ohio.

An interesting parallel project to the X-24B was based on similar initial design studies undertaken in the 1960s. There had been considerable USAF interest in developing a Multipurpose Re-usable Spacecraft (MRS) and between 1964 and 1968 Lockheed's Skunk Works was contracted to produce design studies for two-man MRS vehicles.









Top left: **Between 1964 and 1968 Lockheed participated in a series of classified USAF studies for a multipurpose re-usable spacecraft (MRS). This design was wind tunnel tested at a range of speeds from 200mph (320km/h) to Mach 20. It was powered by a fluorine-hydrogen engine and a small turbojet for controlled landings.** Lockheed Martin

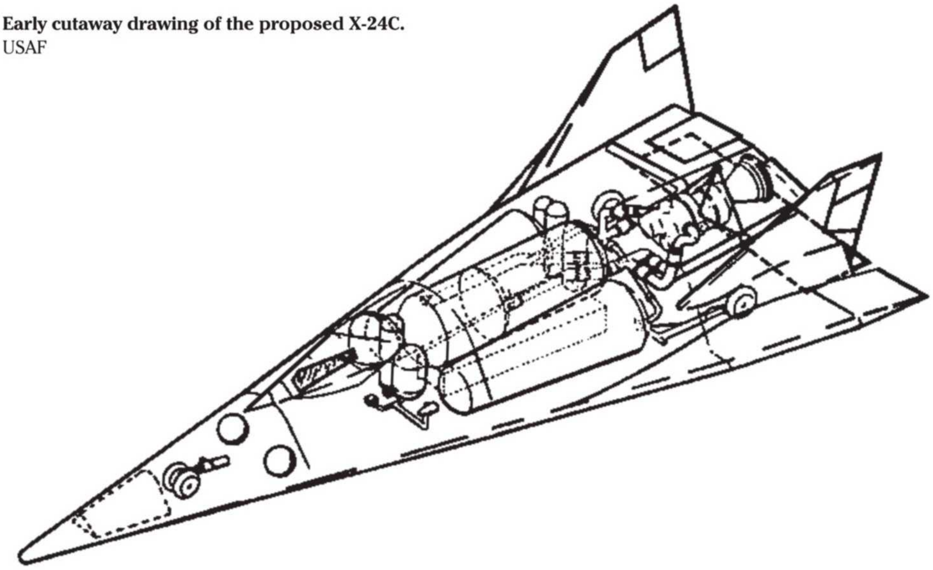
Top right: **One of the Lockheed MRS proposals from the late 1960s based on aerodynamic studies undertaken at the USAF's Flight Dynamics Laboratory.** Lockheed Martin

Centre right: **Lockheed's CL-639 formed part of a substantial military spacecraft study undertaken during the late 1960s, which included various lifting body designs such as the FD-5 and the Multipurpose Re-usable Spacecraft (MRS). Many variations were considered and the CL-639 was a fully reusable three-man design capable of carrying passengers or cargo to an orbiting space station. Powered by an aerospike bell engine, it was also proposed to equip this vehicle with an 8,500 lb (37.8kN) thrust turbojet engine to assist with runway landings.** Pete Clukey/Lockheed-Martin

Bottom right: **The Lockheed CL-1047 was a proposal for a two-stage horizontal take-off spacecraft system. This study began in January 1967 and was commissioned by the USAF at Wright-Patterson AFB, Ohio. The manned upper stage lifting body spacecraft is thought to have evolved from an earlier Lockheed design with the reference CL-655. The large re-usable, winged launch vehicle was to be equipped with six unspecified air-breathing engines providing a maximum speed of about Mach 8.** Pete Clukey/Lockheed-Martin

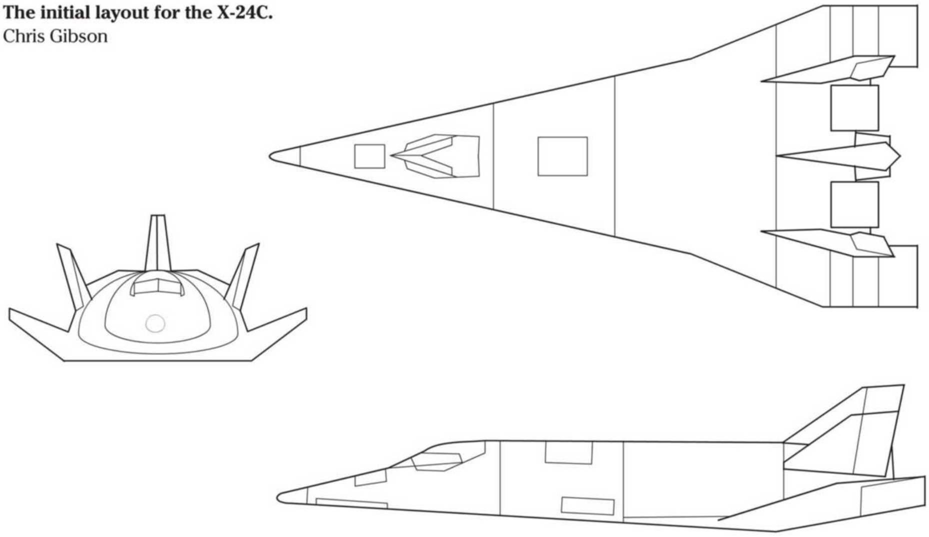
Three classes of vehicle were defined that steadily increased in size and performance. The favoured initial proposal was for a pure delta-shaped vehicle launched by a Titan IIIM booster. It would carry a crew of two in tandem and was to be equipped with a turbojet to facilitate controlled runway landings.

In 1968 the Skunk Works built a mock-up of a two-man orbital vehicle for the USAF, which may have been regarded as a lower cost follow-on from the X-20. It borrowed features



Early cutaway drawing of the proposed X-24C.
USAF

NASA
U.S. AIR FORCE X-24C
MARTIN MARIETTA



The initial layout for the X-24C.
Chris Gibson

from the MRS designs but used a different cockpit layout. There was no jet engine to assist landings and it would have been air-launched from a modified B-52. This small rocketplane received the company designation CL-639-1-167 and was generally known as the Flight Dynamics Laboratory Model 5 (FDL-5). With an estimated length of about 40ft (12m), the manned FDL-5 was to be powered by a single, very compact Pratt & Whitney XLR-129-P-1 throttleable, fluorine-hydrogen-fuelled rocket engine. Most of the propellant would come from two very large jettisonable fuel tanks that would be released when exhausted.

The FDL-5 was not equipped with vertical wingtip fins and used a single small upright stabiliser combined with a contoured rear fuselage. This configuration was described as ‘compression sharing’, although it came with the penalty of degraded low-speed handling. To offset this deficiency and improve control during landing, small flip-out wings were installed and flaps were fitted to the trailing surface. The undercarriage arrangement is somewhat unclear, but it appears to have comprised a conventional nosewheel and X-20 style skids. Another X-20 feature was a jettisonable cover to protect the windshield during ascent and re-entry. The airframe was to be built from aluminium and titanium with columbium and Inconel employed in key areas. Both manned and unmanned versions of the FDL-5 were proposed for orbital operations that included ASAT and limited reconnaissance missions, as dictated by the small payload capacity. Wind tunnel testing of models was undertaken and there have been claims that the mock-up seen in two photographs actually shows a prototype vehicle that was secretly flown between 1969 and 1973. Whether an FDL-5 vehicle was built and tested remains unknown and, officially, the FDL-5 never progressed beyond the mock-up phase. However, the enduring secrecy seems to suggest that a black budget prototype is a distinct possibility.

In 1974 both NASA and the USAF expressed interest in a successor to the X-24B. It would be larger in size and equipped with the XLR-99 liquid-fuel rocket engine developed for the X-15. The aim was to explore speeds up to Mach 8 and eventually conduct scramjet propulsion experiments. Two aircraft designated X-24C were to be built and they would undertake at least two hundred flights over a ten-year period, starting in around 1980. Several defence contractors including

Centre: **A mid-1970s proposal made by Martin Marietta for the X-24C.** Bill Rose

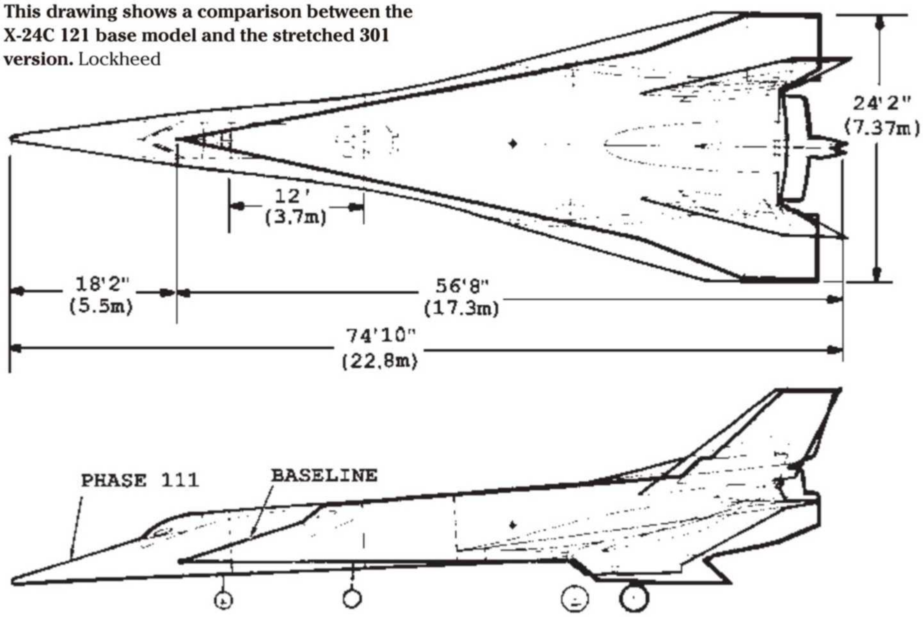
Lockheed and Martin (still separate companies at this time) drew up proposals for the X-24C, which would have been based on the FDL-8 configuration. NASA estimated the cost of the project to be $200 million.

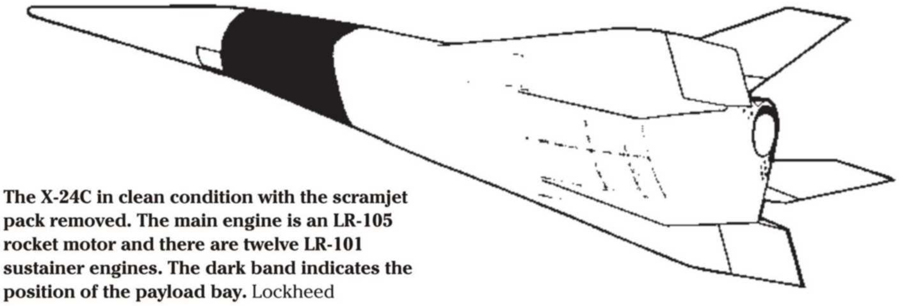
Lockheed appears to have been the favoured contractor to build this manned hypersonic replacement for the X-15 and studies began at the company's Skunk Works facility in Los Angeles. The Lockheed design team was headed by aerodynamicist Henry G Combs and the company study for NASA (CR-145274) officially lasted from late 1975 to early 1977. Combs began by establishing the baseline X-24C and then working on improvements and proposals for a larger vehicle which would lead to the wind tunnel testing and possibly a scale model that could be launched from the back of an SR-71. The airframe would be built from a Lockheed developed composite of aluminium and beryllium called Lockalloy.

The favoured propulsion system for the initial rocket-powered design was a single Rocketdyne LR-105 liquid fuel engine, plus twelve small Rocketdyne XLR-101 sustainer engines for cruise. The second choice was a Thiokol XLR-99 plus two XLR-11 sustainers. Documentation also mentions the option of air-breathing modifications to the fuselage, perhaps suggesting the use of conventional jet engines that would allow normal runway take-offs and landings. Un-powered and rocket-powered flights would begin with air launches from a B-52 at 45,000ft (13,716m). Eventually, zoom climbs would be attempted and the X-24C was expected to reach an altitude of about 45 to 55 miles (72 to 88km) and a maximum speed slightly in excess of Mach 8. Hypersonic cruise at a maximum speed of Mach 6.7 was also possible for a duration of forty seconds at an altitude of 90,000 to 100,000ft (27,400 to 30,500m), but this would be limited by two factors – thermal management and the amount of fuel that could be carried.

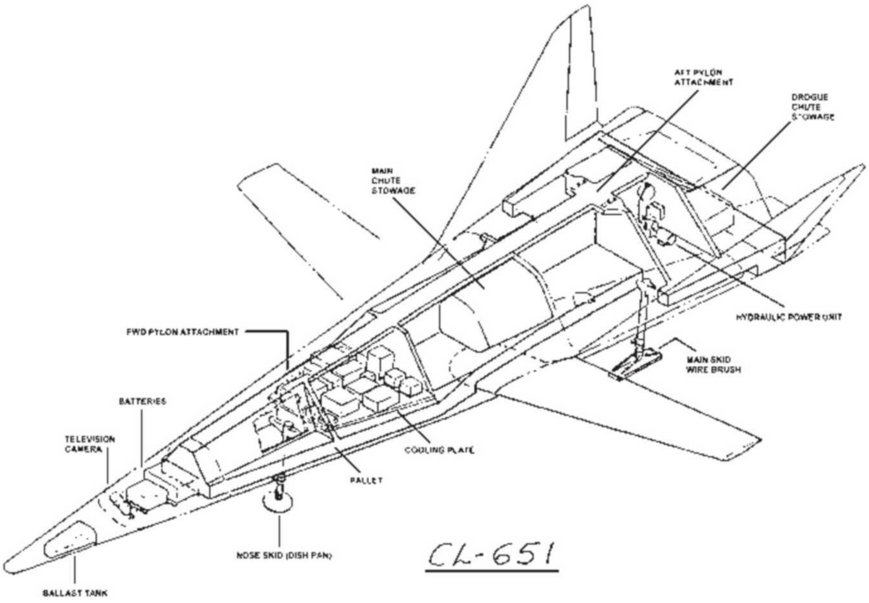
The 75° delta shape had an initial overall length of 53ft 8in (16.4m), but this was

This drawing shows a comparison between the X-24C 121 base model and the stretched 301 version. Lockheed





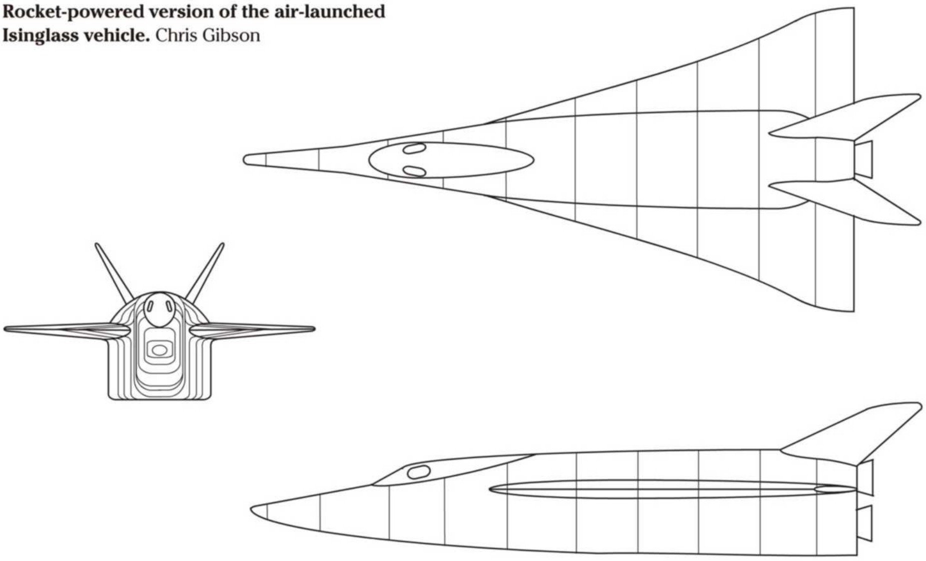
The X-24C in clean condition with the scramjet pack removed. The main engine is an LR-105 rocket motor and there are twelve LR-101 sustainer engines. The dark band indicates the position of the payload bay. Lockheed



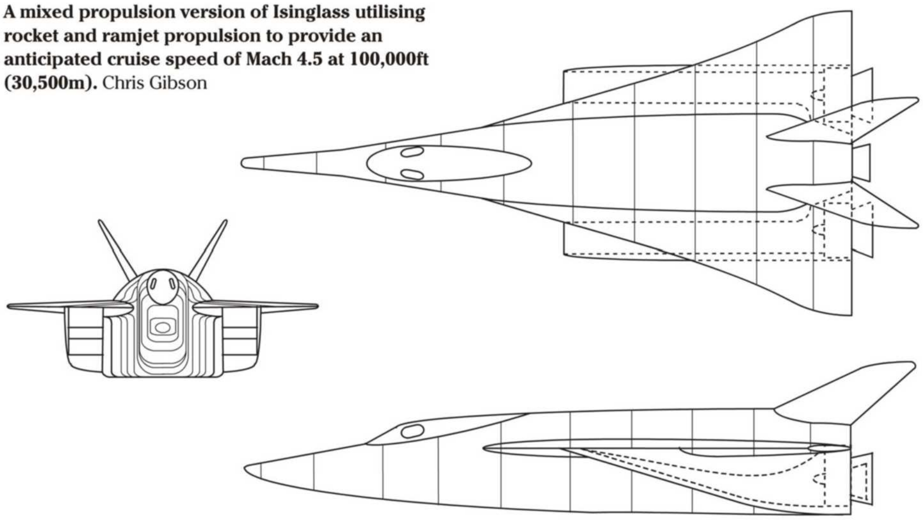
The Lockheed CL-651 was part of a USAF-sponsored project to develop a small air-launched test vehicle to examine supersonic to landing free flight using a lifting body design. This programme produced about ten distinct designs that were all capable of being air dropped from a number of different USAF fighters and bombers. Each design was a lifting body configuration and some had auxiliary wings for low-speed handling, which can be seen in this illustration. The project was linked to proposals for larger re-entry vehicles and one example of the CL-651 was apparently built and possibly tested. Exact specifications and dates for the CL-651 are unknown. Pete Clukey/Lockheed-Martin stretched slightly by the Combs design team to 56ft 7in (17.3m). Span was 24ft (7.3m) and the launch mass about 57,000 lb (25,854kg). The cockpit layout would be similar to the X-15 and X-24B, with a side controller connected to a three-channel fly-by-wire system. A standard ejector seat would be fitted and a tricycle undercarriage based on landing gear designed for the F-106 was planned. Lockheed placed considerable emphasis on thermal issues and proposed several solutions for heat shielding, with the use in key areas of tiles developed for the Space Shuttle. Combs went on to suggest that the X-24C could be stretched to 74ft 10in (22.8m), giving a higher gross weight of 70,000 lb (31,751kg) and allowing the 10ft (3.048m) long payload bay to be increased to 12ft (3.65m). Although there would be advantages in a size increase, this was the maximum possible because of the practical restraints imposed by the B-52 launch aircraft. This larger version designated X-24C LC-301 would carry a special module below the rear of the fuselage that contained experimental air breathing scramjet engines. Lockheed indicated that the first X-24C could be delivered in 1980 and it believed that powered flights could begin in 1983.

Interestingly, the USAF considered another design that was closely related to the X-24C. Known as the Hypersonic Technology Integration Demonstrator (HYTID), this concept appeared to be a cross between Lockheed's submission for the X-24C and the delta winged X-15A-3. HYTID had an overall length of 69ft 9in (21.25m), a span of 24ft (7.3m) and a straight 72° wing sweep; small triangular stabilisers covered in Inconel were fitted to the wingtips. Propulsion would be provided by one XLR-99 rocket engine, plus XLR-11s to sustain hypersonic cruise. Little more has surfaced about this alternative study, but on 1st September 1977 the USAF and NASA officially cancelled the X-24C project due to budget overruns. Suggestions were made that development costs had now risen to $500 million. At least this has always been the stated reason, but it is conceivable that the X-24C continued to evolve with black budget funding as a possible replacement for the Lockheed A-12/SR-71 spyplane.

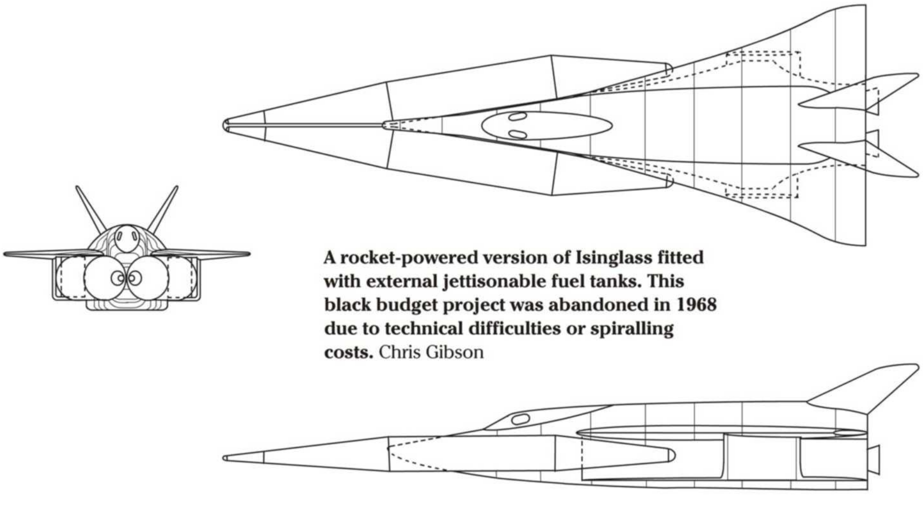
The USAF, supported by the CIA, had already considered a manned successor to the A-12/SR-71 in 1965 and contracted General Dynamics to examine the possibility of developing a new air-launched long-range reconnaissance vehicle codenamed Isinglass. This craft would cruise at a speed of around Mach 4.5 at an altitude of 100,000ft (30,500m). The propulsion system remains classified, but various combinations of turbo-



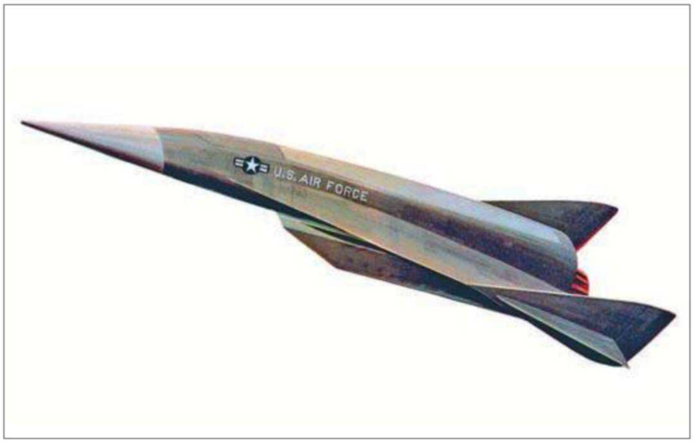
Rocket-powered version of the air-launched Isinglass vehicle. Chris Gibson

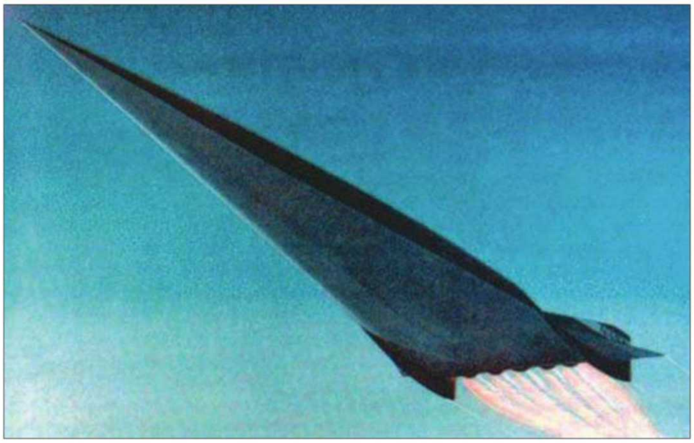


A mixed propulsion version of Isinglass utilising rocket and ramjet propulsion to provide an anticipated cruise speed of Mach 4.5 at 100,000ft (30,500m). Chris Gibson



A rocket-powered version of Isinglass fitted with external jettisonable fuel tanks. This black budget project was abandoned in 1968 due to technical difficulties or spiralling costs. Chris Gibson





Top left: **In the late 1960s a very ambitious USAF/CIA study called Project Rheinberry proposed an air-launched rocket-powered manned reconnaissance vehicle capable of attaining hypersonic speeds on the edge of the atmosphere. The main contractor is understood to have been McDonnell Aircraft, but this highly classified project soon met with cancellation for technical and political reasons. Some aspects of programme were revived by McDonnell Douglas in the early 1970s and appear in this drawing of a hypersonic reconnaissance-strike vehicle called the Aerospace Plane.**

Top right: **A mid-1970s McDonnell Douglas proposal for an air-breathing and rocket powered hypersonic research vehicle.** Both McDonnell Douglas

jet, ramjet and rocket engines were considered. However, this deep black project was abandoned during 1968, either for technical reasons or because of spiralling costs.

An even more ambitious USAF/CIA proposal was for a high performance spyplane called Project Rheinberry, which came about at the same time as Isinglass. This purely rocket powered air-launched manned reconnaissance vehicle was expected to attain a speed of at least Mach 18 at an altitude of 200,000ft (61,000m). McDonnell Aircraft completed extensive studies but the project was scrapped around the same time as Isinglass, and for similar reasons.

Alternatively, it has been suggested that Rheinberry and Isinglass were flawed from the outset, because any launch from a B-52 towards the Soviet Union might have been misinterpreted as a missile attack. However, some elements of the Rheinberry design were revived by McDonnell Douglas at the start of the 1970s and scaled up in size to become a military air-breathing reconnaissance-strike vehicle called the Aerospaceplane. Nothing came of this proposal, but research continued for some time with low-level NASA and DoD funding. The shape remained unchanged as a highly swept delta, but during the mid-1970s it was decided to use six turbo-ramjet engines with a dorsal air intake to power the vehicle. Another closely related McDonnell Douglas design emerged in the early 1980s. This was for a Mach 12 air-breathing and rocket powered military reconnaissance vehicle that had the ability to operate from conventional runways and was apparently capable of reaching orbit.

Some of these projects appear to be over-ambitious, bearing in mind that towards the end of the 1970s Henry Combs expressed serious doubts about the possibility of building an aircraft capable of sustaining hypersonic speed for more than a brief period with prevailing technology. This was probably a realistic assessment and the USAF may have concluded that a near-future military development of the X-24C would only provide a modest performance improvement over the SR-71. But in the longer-term this project might lead to an orbital vehicle with the ability to operate from a conventional runway and, for this reason, the X-24C was an obvious step in the right direction.

US ROCKET & BALLISTIC MISSILE DESIGNATIONS (Significant Designs)

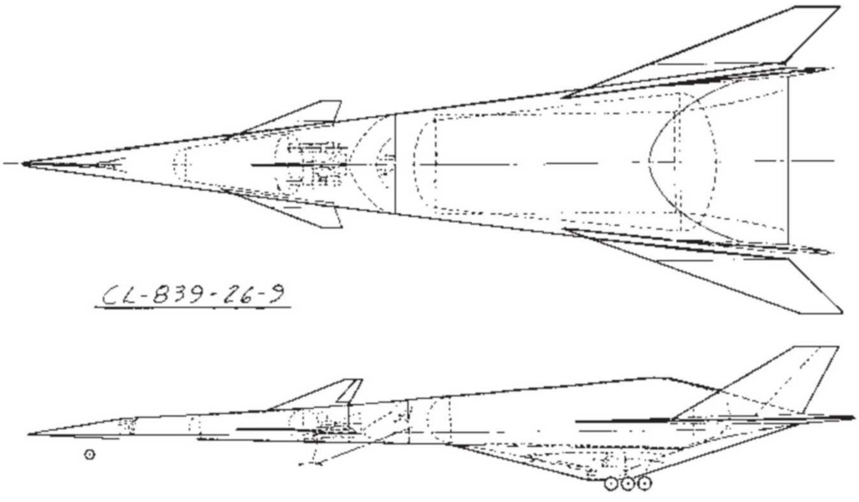
Rocket	Name	Contractor	Alt Designations/Remarks
–	V-2 (A-4)	Captured German	
RTV-G-1	WAC Corporal	JPL	RV-A-1
RTV-G-2	Corporal E	JPL/Firestone	RV-A-2
RTV-G-3	Hermes II	General Electric	RV-A-3, RTV-G-6, SSM-A-9
RTV-G-4	Bumper (V-2 + WAC Corp)	General Electric	RV-A-4
CTV-G-5	Hermes A-1	General Electric	RV-A-5, SSM-15
SSM-G-13	Hermes A-2	General Electric	SSM-A-13 (based on A-1)
SSM-G-14	Redstone	Chrysler	SSM-A-14, M8, PGM-11A
SSM-G-17	Corporal	JPL/Firestone	SSM-A-17, M2, MGM-5A/B
PGM-16A/B/C/D Atlas	Convair (GD)	B-65, SM-65 / WS 107A-1	
PTM-16D/E	Atlas (Trainer)	Convair (GD)	USM-65D/E
HGM-16F	Atlas	Convair (GD)	SM-65F
PGM-17/A	Thor	Douglas	B-75, SM-75 USM-75
PGM-19A	Jupiter	Chrysler	SM-78
HGM-25A/B	Titan I	Martin Marietta	B-68, SM-68 / WS 107A-2
HGM-25C	Titan II	Martin, Lockheed-Martin	SB-4A, LGM-25C
	Titan III	Martin Marietta	
	Titan 34D	Martin Marietta	SB-6A based on Titan IIIC
	Titan IV	Martin Marietta	SB-5A/B
LGM-30A/B/C	Minuteman I	Boeing	
LGM-30F	Minuteman II	Boeing	
LGM-30G	Minuteman III	Boeing	
LGM-118A	Peacekeeper	Boeing/Martin Marietta/TRW	
UGM-27A/B/C	Polaris	Lockheed	A-1, A-2, A-3
UGM-73A	Poseidon	Lockheed	C-3
UGM-96A	Trident 1	Lockheed	C-4
UGM-133A	Trident 2	Lockheed Martin	D-5

Aurora, Myth or Reality?

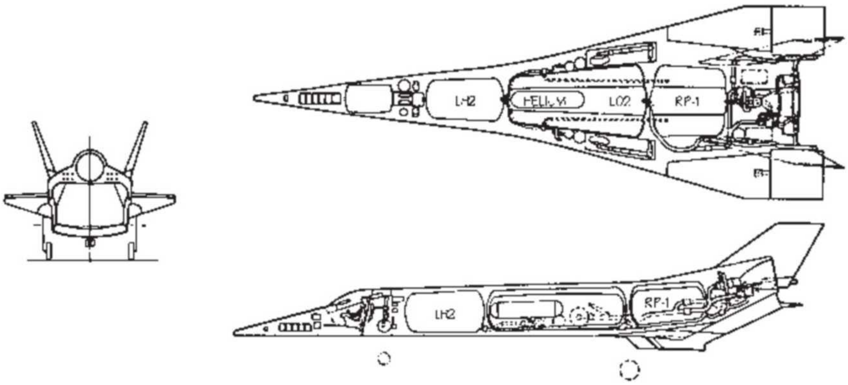
Lockheed's proposal to build the hypersonic X-24C-L301 test vehicle for NASA and the USAF was officially cancelled in late 1977 due to funding restraints, but there is a growing belief that studies actually continued at the Skunk Works within a highly classified military programme possibly called Copper Coast. McDonnell Douglas may have been initially involved with this project and that company is known to have developed configurations based on the FDL-7 as part of the company's aerospace plane programme.

But circumstantial evidence would seem to indicate that Lockheed became the chosen contractor. The USAF and CIA were seeking a next-generation spyplane and the X-24C project was undoubtedly perceived as a useful stepping-stone towards the realisation of this goal. Work on a highly classified project of this nature would have lasted for several years with a schedule that followed much the same course as the proposed 'white world' X-24C. Conceivably, two test aircraft were completed by the early 1980s with delivery taking place at Groom Dry Lake, Nevada. While this scenario remains a matter of supposition, it is apparent that the USAF was urgently seeking a suitable replacement for the ageing Lockheed SR-71 and feared becoming reliant on satellites, the high-altitude U-2 and drones for most of its reconnaissance operations. Strong indications that the X-24C was far from dead began to surface at the end of the 1970s when the USAF briefly discussed ideas for a manned Mach 4 strategic reconnaissance aircraft. This would be capable of operating at an altitude of 200,000ft (61,000m) and enter service by 1990. Rightly or wrongly, it is tempting to conclude that it was talking about a classified project that was under way, and perhaps the USAF initially considered disclosure as the government was somewhat more open in those days.

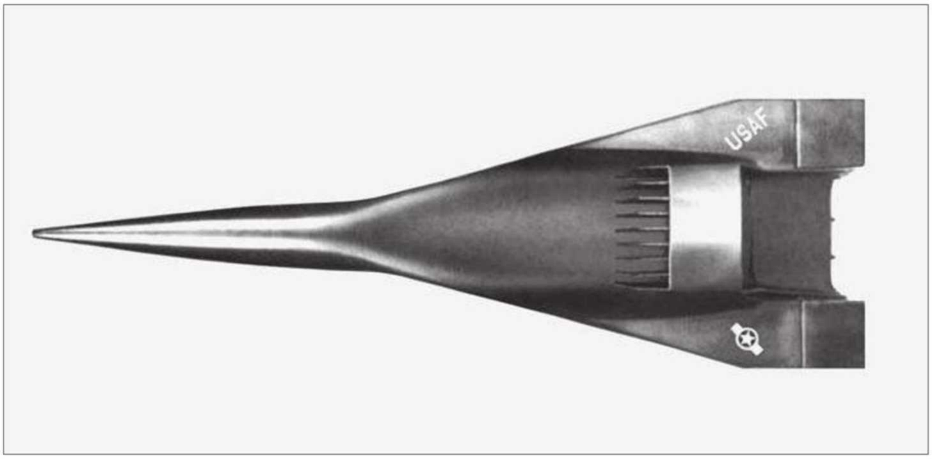
If the trials of an air-launched prototype went well the design might have been scaled-up in size, resulting in a vehicle with a length of about 100ft (30m) that was capable of making take-offs from a conventional runway under its own power. The most likely choice of propulsion would be a combination of turbojet and ramjet engines, with more advanced systems being considered but probably regarded as too risky for use in the short-term. Intriguingly, Lockheed was allowed to release concept artwork to the public domain in 1981 which depicted a large hypersonic SR-71 replacement with a length in excess of 130ft (39.6m). Accompanying detail said that this aircraft was expected to reach a maximum altitude of about 100,000ft (30,500m) and cruise at Mach 5. Propulsion would be provided by four turbo-ramjets running on liquid methane and most of the structure would be built from titanium and stainless steel. The artwork was later described as part of a study which ended in 1986, but the timing of the release may have



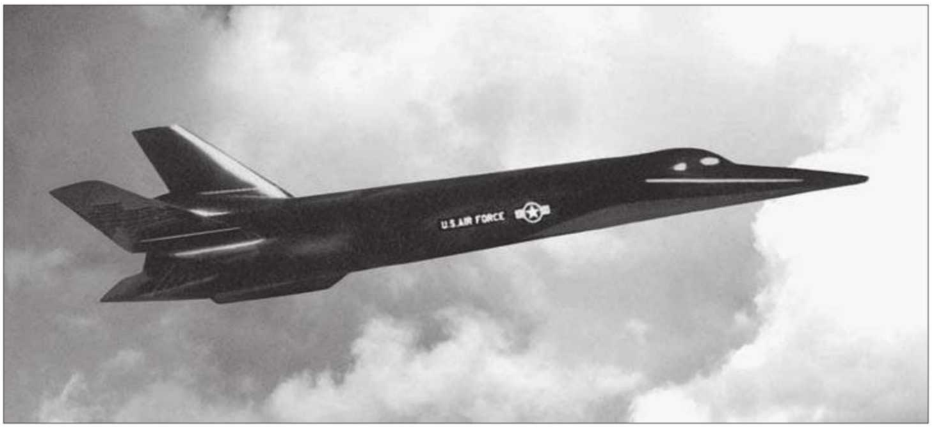
Described as a tandem staged hypersonic vehicle, little information is available for the Lockheed CL-839-26-9. This design appears to have followed Lockheed's MHCV study and both components of the CL-839-26-9 system are manned, re-usable and capable of making horizontal landings. Pete Clukey/Lockheed-Martin



This illustration was prepared by Lockheed's Skunk Works and shows the proposed layout for the L301 stretched version of the X-24C research aircraft. Lockheed Martin



A scale model of the proposed X-24C-L301 with scramjet propulsion unit. Lockheed Martin



Simulation of the Lockheed X-24C-L301 in flight. Bill Rose

been significant as the design looked nothing like the X-24C and was more of a science-fiction adaptation of the SR-71, perhaps intended to distract attention from what was really taking place. Throughout the 1980s rumours of a hypersonic spyplane persisted and in 1988 a story appeared in the *New York Times* announcing that a top-secret hypersonic reconnaissance aircraft with a stealth capability was under developed for the USAF, and that it would soon replace the SR-71.

Although a hypersonic spyplane seemed to be the logical step forward, this newspaper report was denied by the USAF at a 1989 Senate Armed Forces Committee review when it was stated that two research programmes had been undertaken but neither had proved particularly promising. However, events took a dramatic turn on 26th August 1989 when a very unusual sighting took place from the Galveston Key drilling rig, located above the huge Indefatigable Oil Field in the North Sea about 100 miles (160km) due east of the Wash. As usual there was continual military air traffic passing overhead because this region falls within a NATO refuelling zone called AARA-6A. Shortly after midday an engineer working on the rig called Graeme Winton spotted a small formation of aircraft approaching. Normally he wouldn't have given these planes a second glance, but there was something unusual about them and he called to his colleague Chris Gibson to take a look.

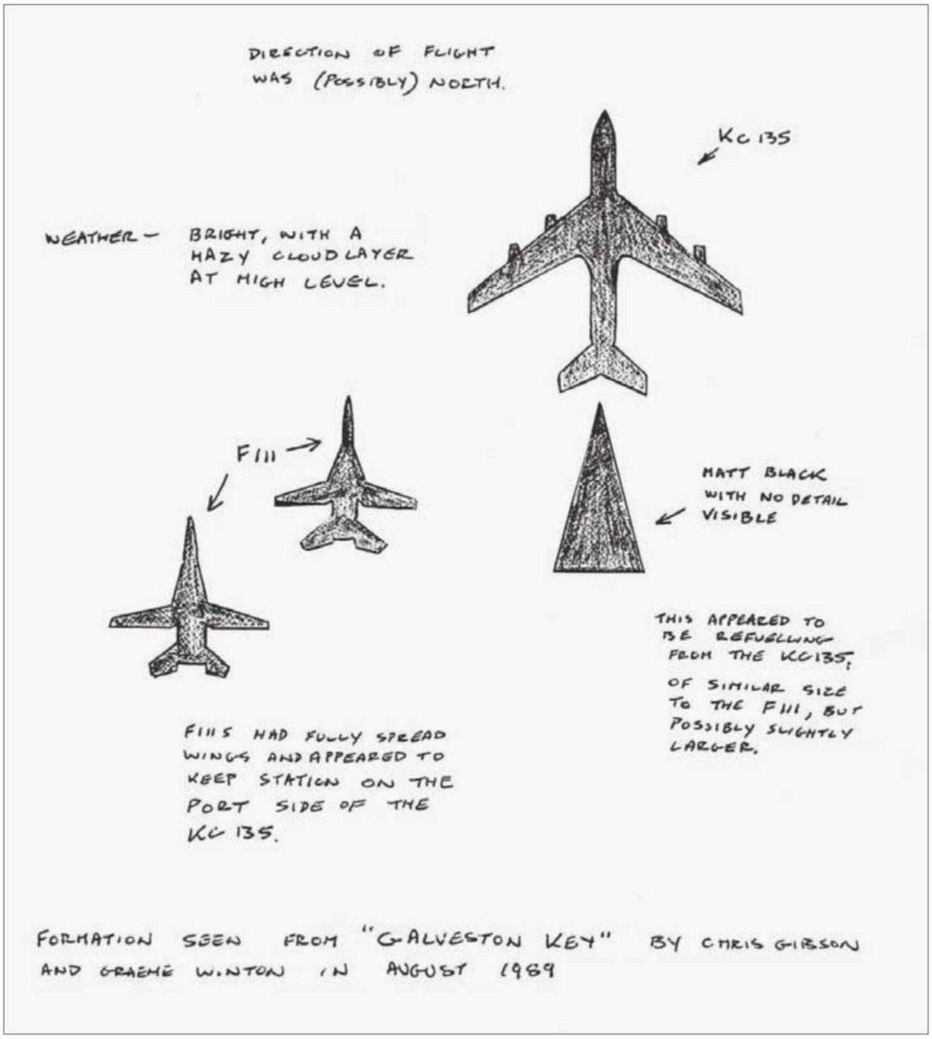
Aside from being an experienced oil exploration engineer, Chris Gibson was a long-term member of the Royal Observer Corps (ROC), an acknowledged expert on military aircraft recognition and is now a well-known aviation writer. For the best part of two minutes, both engineers studied the aircraft as they passed directly overhead in a northwest direction, at an estimated altitude of about 10,000ft (3,048m).

The formation was led by a Boeing KC-135 tanker which was closely followed by a sharply swept featureless black triangle that appeared to be in a refuelling position. Two other aircraft completed the group and these were General Dynamics F-111 bombers with their wings fully extended. Chris Gibson was totally baffled by the mysterious black triangle and couldn't think of any aircraft that matched its appearance. In the following weeks he discussed the incident with several close friends within the ROC, although members of this organisation were subject to the British Government's strict Official Secrets Act and this discouraged him from going public with the unusual sighting.

In 1991 the ROC was 'stood down' and Chris Gibson felt that he was able to talk openly about the black triangle. Eventually he made contact with the aviation writer Bill Sweetman, who concluded that the unidentified aircraft might have been a highly classified American spyplane capable of hypersonic speed. Chris Gibson wasn't going to pin a label on the aircraft and, while he accepted that Bill Sweetman was probably on the right track, he limited himself to saying that he had seen a black featureless aircraft with a very unusual appearance that was probably American in origin.

In early 1990 the magazine *Aviation Week & Space Technology* (AWST) printed an article that first mentioned the name Aurora, which it had found in a Pentagon budgetary allocation P-1 document dated 4th February 1985. This indicated that a classified project called Aurora would receive $80 million in 1986 and a massive $2.2 billion in 1987. As the reference to Aurora had appeared on the next line from the TR-1 reconnaissance aircraft, AWST suggested that Aurora was almost certainly the name of the secret SR-71 replacement. When staff at the *Washington Post* newspaper made further enquiries with the Pentagon, they were told that Aurora was nothing more than a special funding programme for the Advanced Technology Bomber (which eventually became the Northrop-Grumman B-2A Spirit Stealth bomber). But somewhat surprisingly, there was no reference to Aurora in the following year's funding document, leaving researchers wondering if they really were dealing with a high-level cover-up. Details of Chris Gibson's North Sea Sighting had now been picked up by the international press who were linking his report to the supposed top-secret Aurora spyplane, and accounts of the incident soon reached the Pentagon.

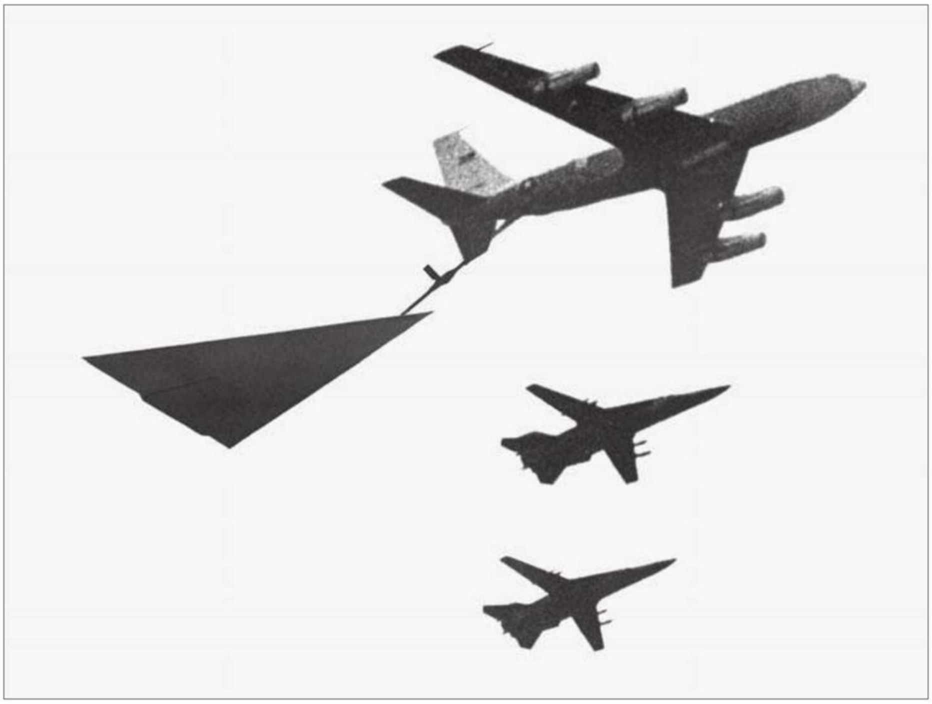
This prompted Brigadier General Walter S Hogle, who headed the USAF's Public Affairs Office, to dismiss the aircraft as an RAF Avro Vulcan, which overlooked the fact that the last of these British bombers had been retired in 1984. However, the only person to seriously challenge Chris Gibson's sighting was the US aviation writer Curtis Peebles who suggested that the mystery aircraft could have been an F-111 with its wings swept back. On the face of it, this theory sounded plausible and it is


DIRECTION OF FLIGHT WAS (POSSIBLY) NORTH.
KC 135
WEATHER — BRIGHT, WITH A HAZY CLOUD LAYER AT HIGH LEVEL.
F111
MATT BLACK WITH NO DETAIL VISIBLE
THIS APPEARED TO BE REFUELLING FROM THE KC135; OF SIMILAR SIZE TO THE F111, BUT POSSIBLY SLIGHTLY LARGER.
F111S HAD FULLY SPREAD WINGS AND APPEARED TO KEEP STATION ON THE PORT SIDE OF THE KC 135.
FORMATION SEEN FROM "GALVESTON KEY" BY CHRIS GIBSON AND GRAEME WINTON IN AUGUST 1989

Left: **Drawing made by Chris Gibson shortly after witnessing the North Sea sighting in August 1989. Later, after more accurate measurements, it was agreed that the direction was more to the northwest.** Chris Gibson

Lower left: **An accurate simulation of the North Sea aircraft formation reported by Chris Gibson and Graeme Winton, which took place in 1989.** Bill Rose

Above: **In response to the report of the North Sea sighting, USAF Brigadier General Walter S Hogle suggested the unidentified aircraft had been an RAF Vulcan, seemingly unaware that this bomber had been retired several years earlier.** USAF



possible to imagine an emergency situation where a swing-wing combat aircraft would need to take on fuel in the fully swept condition. In the case of the F-111 there may have been the need to practice this operation from time to time and perhaps the sighting was nothing more than that?

In fact, the USAF F-111 In-Flight Refuelling Manual directs that wings must be set forward to at least 26° for air-to-air refuelling and, according to one USAF F-111 pilot, this aircraft would become very difficult to control at the normal 300 knots (555km/h) refuelling speed with its wings fully swept at 72°. He indicated that the operation would not be attempted in this manner. Furthermore, it should be noted that both accompanying F-111s were flying with their wings in the forward position. Subsequent investigation suggested that a KC-135Q tanker belonging to 9th SRW had been operating out of RAF Mildenhall in Suffolk on the day of the sighting and the accompanying F-111s almost certainly belonged to the USAF's 48th TFW at nearby RAF Lakenheath. Also significant is the fact that the SR-71 was officially retired from service in March 1990 and the Pentagon insisted there was no longer any requirement for a manned high performance strategic reconnaissance aircraft. Air Force chiefs maintained that in future the USAF would primarily rely on satellites for intelligence gathering, with support from advanced versions of the Lockheed U-2 and pilotless vehicles. Few experienced observers accepted this and it seemed to reinforce the belief that a new aircraft was already semi-operational.

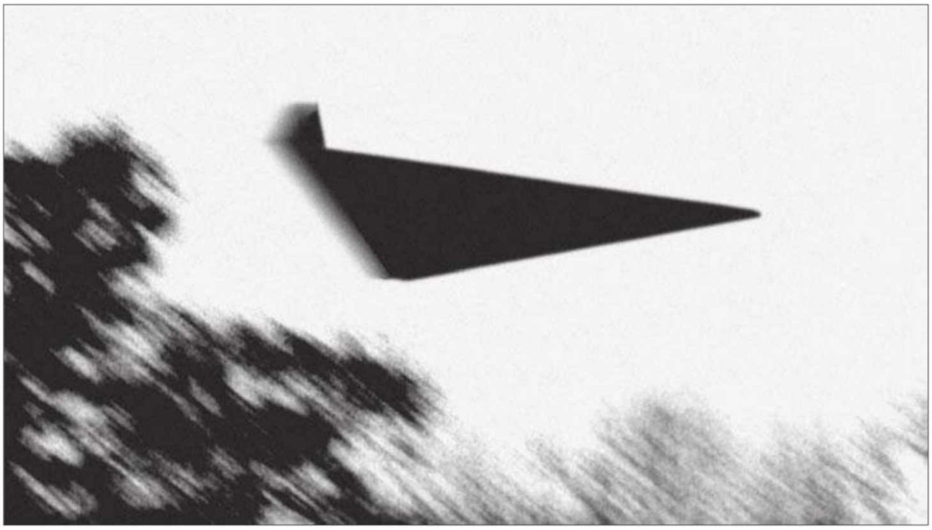
From late 1990 onwards the USAF codename Senior Citizen began to circulate around US defence contractors and this was initially thought to be the official USAF designation for a hypersonic spyplane, but the name now appears to belong to a classified stealthy transport aircraft which may or may not exist. In 1991 an RAF air traffic controller detected an unidentified aircraft leaving RAF Machrihanish, which is a remote base in Scotland allegedly used on occasion by US Navy SEALS (special forces) and as a temporary home for Lockheed F-117A stealth aircraft during the 1980s before the F-117A officially existed. The unidentified radar target observed by the Air Traffic Controller quickly accelerated to Mach 3, and when he contacted RAF Machrihanish they told him to forget what he had seen.

Questions were raised in the British House of Commons and Defence Minister Archie Hamilton responded by simply saying this was, '… a matter for the American authorities'. More unusual engine noises were reported from various locations in the Southwest United States and in February 1992 there were several night-time sightings of a large unidentified diamond-shaped aircraft at Beale AFB, California. Unusual contrails looking like doughnuts on a rope were soon being reported and radio enthusiasts overheard a number of strange messages between US military air traffic controllers and unidentified aircraft operating at unusually high altitudes. From late 1991 onwards scientists at the California Institute of Technology (CalTech) recorded a series of supersonic booms across Southern California that were reminiscent of those produced by the Space Shuttle. These disturbances would occur at specific times of the day and it was possible to establish a flight-path moving in a north north-east direction. But the Shuttle wasn't flying at that time and seismological readings from many earthquake sensors indicated that two unknown aircraft travelling towards Nevada at speeds between Mach 3 and Mach 4 created the shock waves. Further analysis suggested that these aircraft were on approach to Groom Lake and were actually in the process of decelerating!

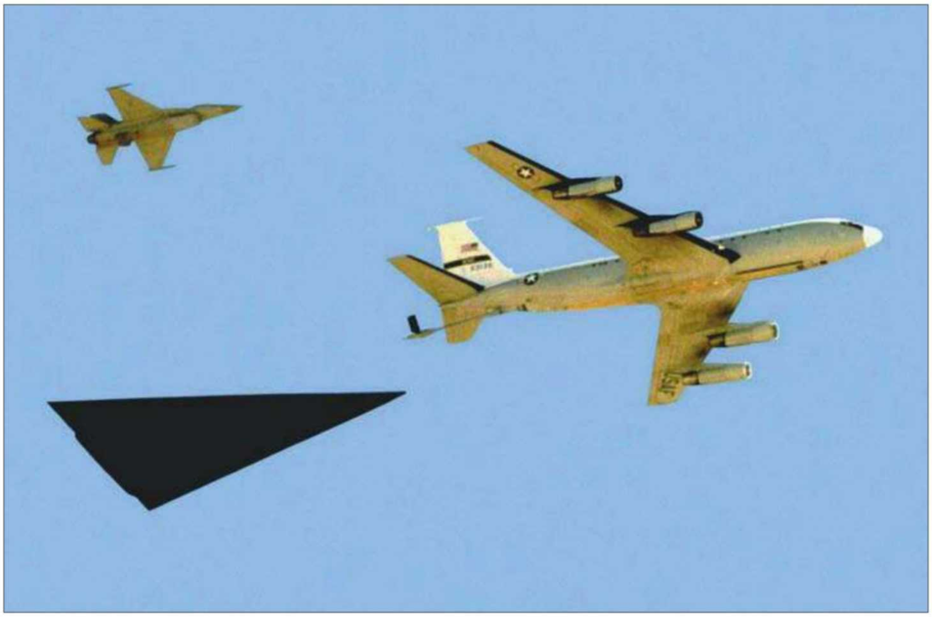
In response to journalist's questions in July 1992, USAF Secretary Donald Rice tried very hard to dismiss the idea of an aircraft like Aurora. He said, 'I can tell you that there is no airplane that exists remotely like that which has been described in some articles'. Martin Faga, who was Director of the National Reconnaissance Office (NRO), also denied the existence of Aurora, saying 'We at NRO have no such vehicle and the Air Force has said the same. I don't know what the Navy, Army, NASA or anybody else is doing, I'm just saying that NRO doesn't have an Aurora, or anything else like it!' In his 1994 book *Skunk Works*, the late Ben Rich (who ran this secret facility) attempted to dismiss the rumour that his facility had been working on a hypersonic aircraft. He claimed that a Colonel Buz Carpenter had been responsible for the 1985 P-1 Weapons Procurement Document and went on to say that the Colonel had arbitrarily assigned the name Aurora, which was nothing more than competition funding for the B-2. Rich also recalled one occasion when he phoned President Reagan's scientific advisor Jay Keyworth to tell him that the idea of developing a hypersonic vehicle was ridiculous. He went on to dismiss the idea, conveniently forgetting to mention Lockheed's considerable interest in this area and past proposals for various hypersonic designs.

Whatever the truth, there was now considerable speculation within the aviation community that Aurora not only existed, but a small number had actually entered limited service with the USAF. In addition, the fact that the F-117 stealth interdictor had been vehemently denied for many years only helped to reinforce this belief. Both McDonnell Douglas and Lockheed were being credited as the constructors of this aircraft, with Lockheed regarded as the more likely of the two. Numerous drawings began to appear of two-man triangular vehicles with the classic 75° sweep and expectations were running high that the Pentagon would soon be obliged to disclose the existence of this aircraft. Then the idea that Aurora was powered by exotic air breathing Pulse Detonation Wave Engines (PDWE) running on cryogenic fuel began to take hold. Hydrogen (LH2) was considered the obvious choice, but this fuel's relatively low density suggested that methane or Methylcyclohexane (MCH) might be a better solution for any aircraft designed to sustain speeds of Mach 4 to 6. Some observers believed that the PDWE would explain the exceptionally loud unexplained engine noises and the strange contrails that appeared in some areas. As to what parts of any mission would be undertaken at high supersonic cruise or possibly hypersonic speed was never explained, but it should be remembered that any long-range, high-speed mission would consume vast amounts of fuel.

While many military combat aircraft can achieve supersonic performance for brief periods, sustained supersonic speed is an entirely different issue and supercruise is a relatively recent concept linked to enhanced engine performance without the use of an afterburner. For example, the single-engined Lockheed Martin F-16A Fighting Falcon is capable of reaching Mach 2 (about 1,288 knots/2,385km/h), but this speed is only possible at high altitude when the aircraft is a 'clean' condition and it requires the use of full military thrust which burns fuel at the rate of 2 US gallons (7.5 litres) per second. So, the



Simulation of a snatched photograph of a hypersonic aircraft leaving a remote airfield on a clandestine mission. Bill Rose



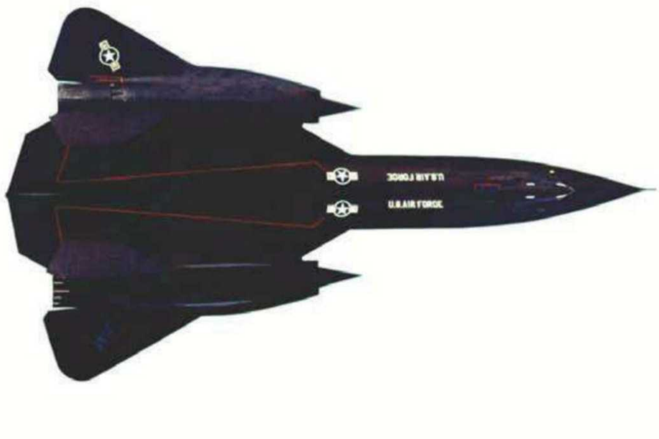
two main issues with high performance flight are rapid fuel depletion and increased engine wear. With this in mind it seems reasonable to assume that a hypersonic military aircraft flown operationally would involve the use of several tanker aircraft.

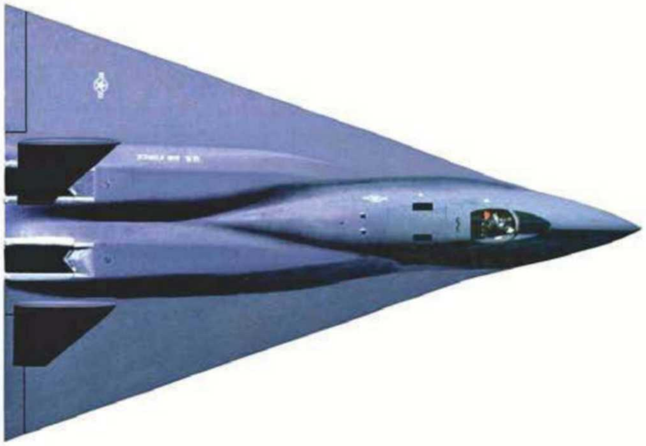
The cruise speed and range of an Aurora class vehicle can only be guessed at, but various sightings would suggest occasional long-range test-flights have taken place from Groom Lake to secure sites in the Pacific or somewhere like RAF Machrihanish in Scotland. The likelihood of such an aircraft undertaking operational missions is anyone's guess! While sporadic sightings of unidentified military aircraft attributed to Aurora continued throughout the early 1990s, few individuals outside the US military had the faintest idea what the true situation was. Then the 1994 Senate Appropriations Committee allocated $100 million for the refurbishment of three SR-71s which were to be used to close a perceived 'intelligence gathering gap' revealed during the Gulf War. To some observers this announcement

Since the early 1990s many reports of unusual contrails have been attributed to secret high performance spyplanes, but in reality the majority have rather mundane explanations like this example which was produced by a commercial jet passing over eastern England in 2005. Bill Rose

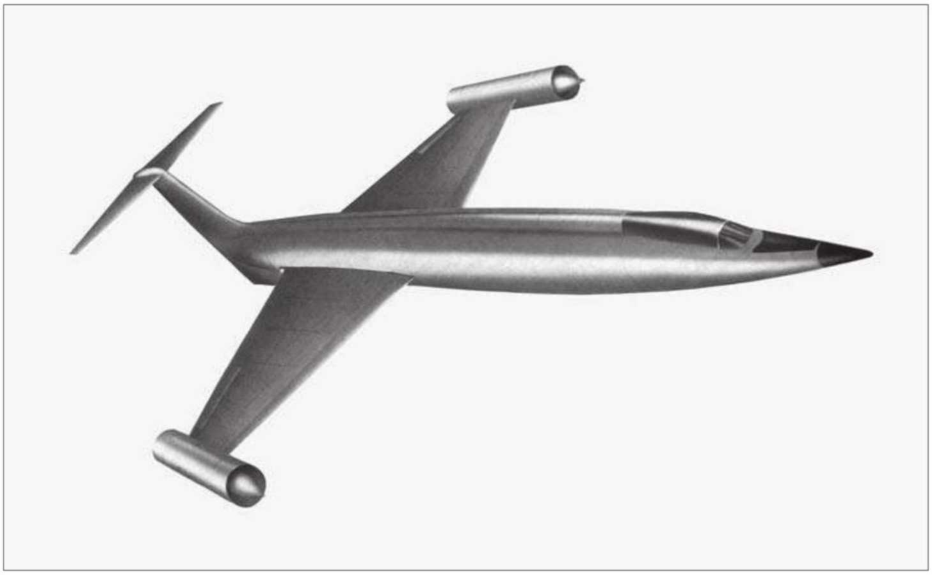
Simulation of a classified US hypersonic aircraft undergoing in-flight refuelling. Bill Rose

If a manned aircraft has entered limited service with the USAF/CIA as a replacement for the SR-71, it may provide similar maximum performance but will be easier to fly and should offer significant improvements in the areas of preparation time, maintenance and operating costs. The artwork shows a hypothetical reconnaissance development of the Northrop YF-23A optimised for high-altitude supersonic cruise. Bill Rose

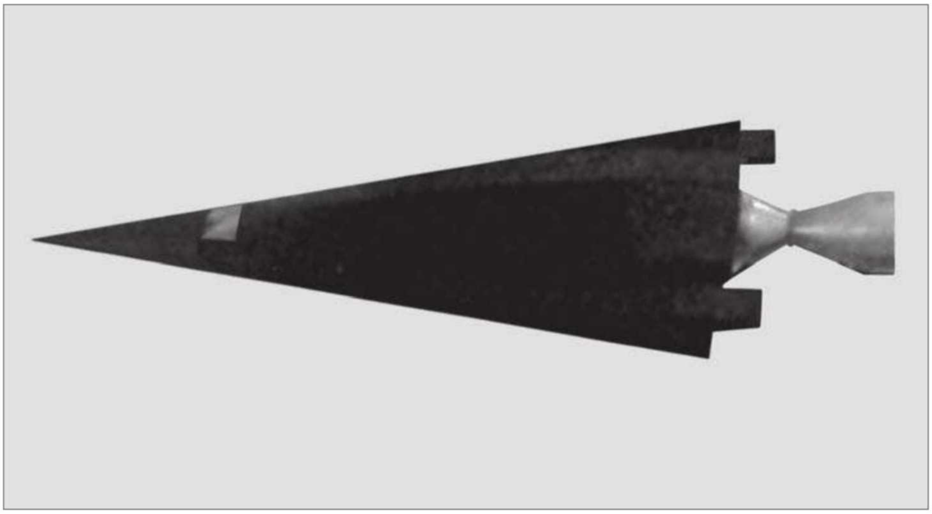




During the 1950s, Lockheed worked on a hydrogen-fuelled supersonic spyplane called Suntan, but the design was too ambitious and the project finally met with cancellation. As a consequence, Suntan's existence remained secret for several decades.
Lockheed



The classified air-launched Hypersonic Glide Vehicle or HGV was developed as a means of testing the delivery of nuclear warheads and it appears to be based on design work undertaken by the USAF Flight Dynamics Laboratory.
via Bill Rose



reinforced their belief that no expense would be spared to debunk reports of a new spyplane and the theory gained weight when the USAF shut down all SR-71 operations for six months in 1996. The following year the last USAF SR-71 was permanently retired without ceremony.

After this many respected observers began to revise their opinions about Aurora, suggesting that several prototypes may have been built and flown but serious technical problems arose or colossal development costs brought the programme to a halt. There is certainly some justification for this theory because during the 1950s a very advanced US supersonic spyplane called Suntan was scrapped due to insurmountable technical issues and it remained highly classified for decades; some of the details are still unavailable.

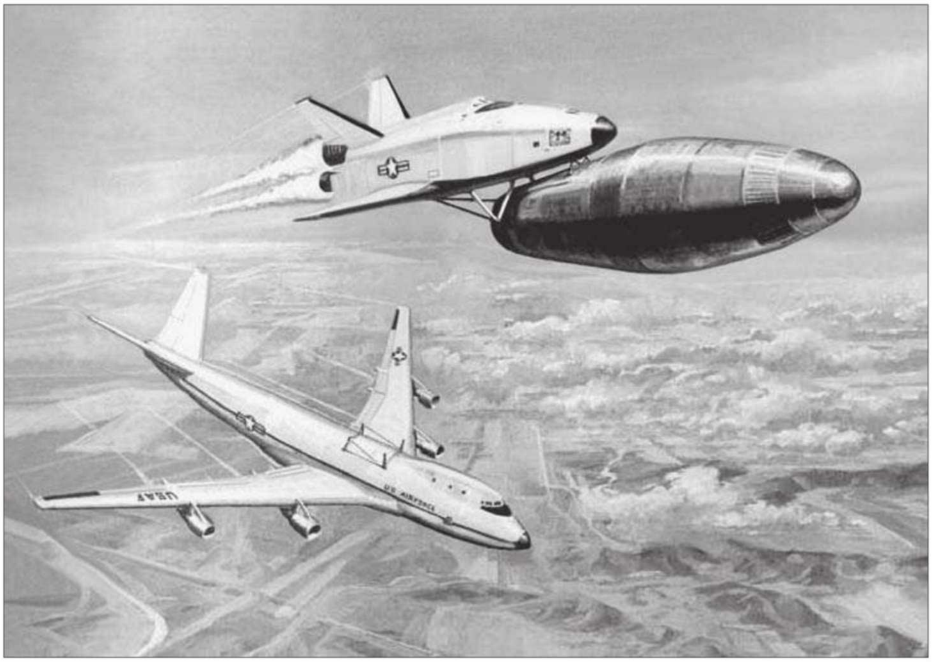
It is also true that for fifteen years the Pentagon insisted that the F-117A simply didn't exist. So conceivably, a manned successor to the SR-71 was developed and small numbers of these aircraft may or may not be in service. While Aurora's existence remains contentious, the UK MoD released a report on Unexplained Aerial Phenomena (UAP) in UK airspace in May 2006. Originally produced by the Defence Intelligence Staff (DIS) in 2000 and classified as top secret, one section attributes some UAP sightings to classified aircraft projects which may be US in origin. Images are blanked out and just the fact that sightings have occurred in the UK is intriguing.

If we are willing to accept that the X-24C was used as the starting point for several classified programmes, this might also explain the Lockheed Hypersonic Glide Vehicle (HGV) which was initiated by the Skunk Works in the late 1970s. The unmanned HGV was a delta-winged rocket-powered vehicle with 75° of sweep which had the appearance of a scale-sized X-24C with a length of about 30ft (9.1m). Using a rocket booster the HGV was to be air-launched from a B-52 at high altitude and would reach a speed of Mach 18. With an estimated range of 5,000 miles (8,046km) the HGV would be used as a test vehicle for a rapid reaction weapon carrying two or three independent nuclear warheads. Some uncorroborated reports suggest that test flights were undertaken towards the end of the 1980s, although nothing more is known about this highly classified project.

Spaceplanes

Was the Aurora an experimental high-performance aircraft based on the X-24C that proved too expensive or technically demanding to develop fully? Or could it have been an intermediate step towards a more ambitious multi-billion dollar deep black space vehicle intended for operational use by the early 1990s? There is still some confusion about the USAF's designations, but it would appear that Copper Coast was applied to a development of the X-24C project, and this was soon followed by a more ambitious proposal called Copper Canyon that aimed to provide the USAF with an SSTO or TSTO spaceplane.

Unpublicised USAF interest in small spaceplanes continued after the demise of the X-20 and one study to generate considerable interest during the same period as the X-24C was the Air-Launched Sortie Vehicle (ALSV), which also remains largely classified. The main component of this proposal was a small manned or unmanned spaceplane launched from the back of a heavily modified Boeing 747-200. The ALSV was to be powered by nine RL-10 liquid-fuel rocket engines of the same type used for the Centaur stage and it would use a large expendable fuel tank that would be jettisoned at an altitude of approximately 67 miles (108km). Boeing, Rockwell and Lockheed developed different proposals for the ALSV which all resembled a scaled-down Shuttle. The exception was a fully re-usable ALSV designed by General Dynamics, although this concept appears to have been eliminated at an early stage due to its technical complexity. It was planned to equip the



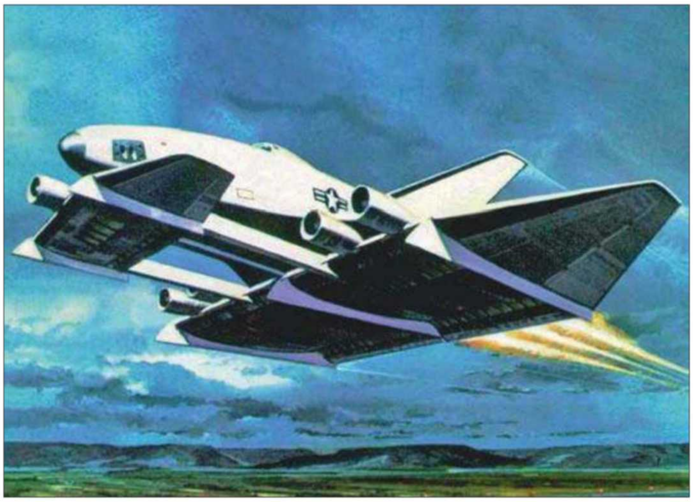
Left: **Another image showing an ALSV launch from the back of a modified Boeing 747-200. In this case the carrier aircraft has a V-tail.** USAF

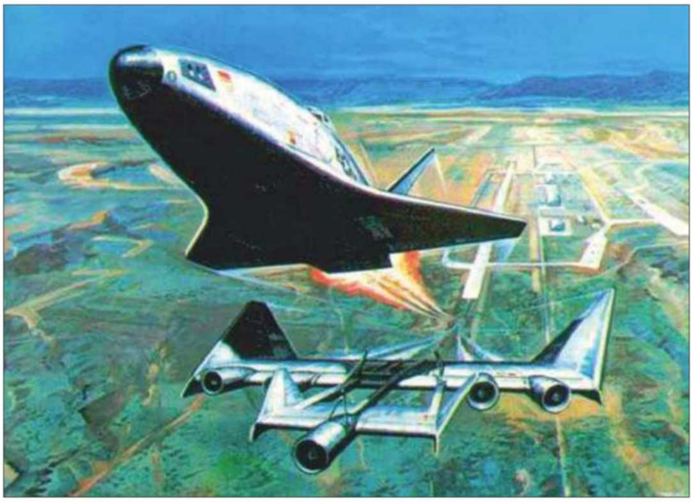
Centre left: **The spacecraft carried by this large jet powered 'Flying Sled' appears to be a variant of the USAF's air-launched Sortie Vehicle, but there is no expendable fuel tank. This may indicate that the Flying Sled was designed to allow short test flights, or alternatively this spacecraft is larger than its appearance suggests.** Rockwell

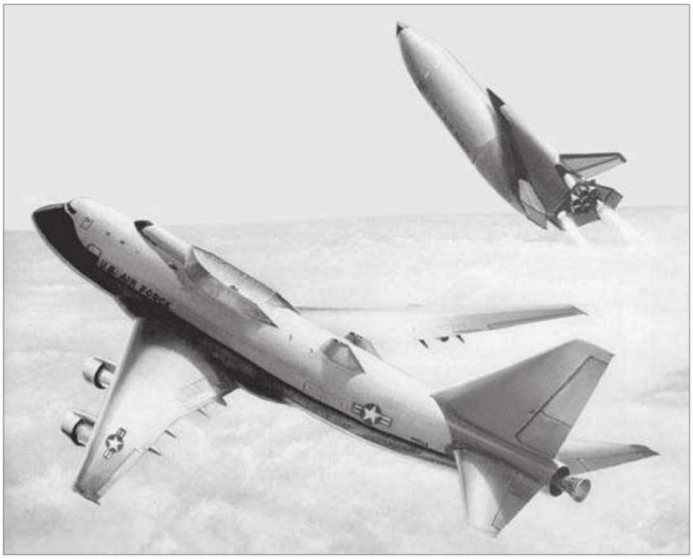
Centre right: **Rockwell illustration showing a spacecraft launched by a jet-powered 'Flying Sled' with separation taking place at a relatively low altitude. The spacecraft appears similar to some designs for the USAF's Air-Launched Sortie Vehicle, but would need to be larger to undertake the same role since it does not carry an expendable fuel tank.** Rockwell

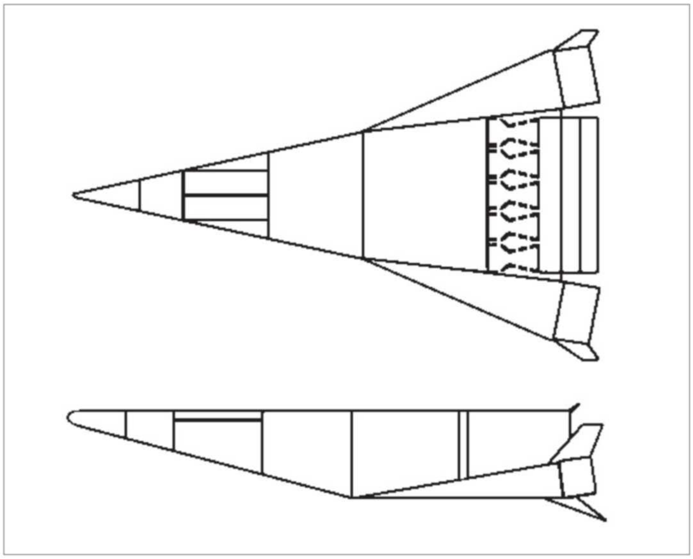
Bottom left: **The release of an unmanned seven-engine version of the Boeing Air-Launched Sortie Vehicle (ALSV) launched from a much modified Boeing 747-200.** USAF

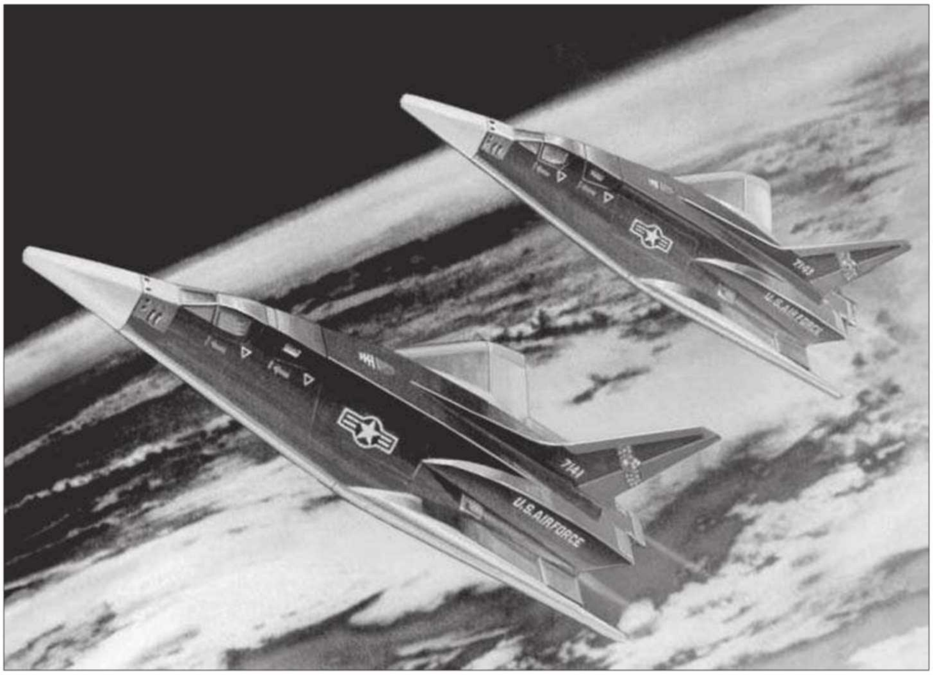
Bottom right: **A later ten-engine configuration of the unmanned Boeing Sortie Vehicle.** Bill Rose

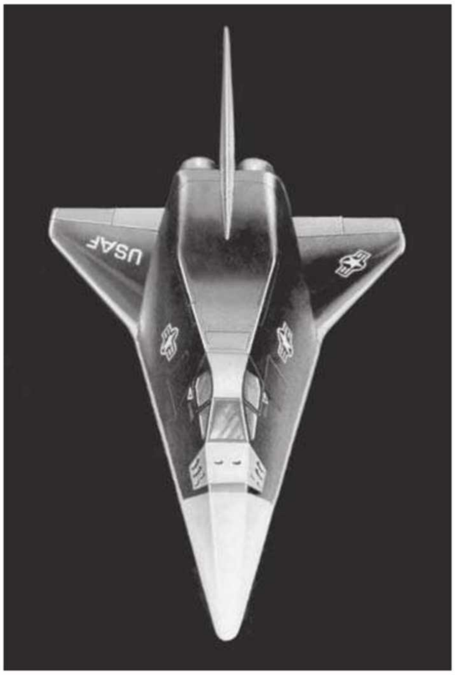












Above left: **The USAF's Trans-Atmospheric Vehicle (TAV) study aimed to produce a combat aircraft capable of operating in a range of different environments from orbit to low-level.** Rockwell

Above right: **The TAV programme examined the idea of building a super flexible F-111 replacement which could be carried into orbit and function as a spaceplane or fly as a jet-powered strike aircraft. Although an interesting concept, the technology required to make this idea work remains unattainable.** Rockwell

modified 747-200 launch vehicle with a special tail unit that contained one or more rocket engines to assist the launch.

Rather perplexingly, some Rockwell artwork shows a design that looks identical to the Sortie Vehicle but uses a large jet-powered unmanned launcher called Flying Sled for horizontal take-off from a conventional runway. Because there was no provision for an expendable fuel tank, it seems likely that the Flying Sled was intended to facilitate short test flights, assuming that the spacecraft was no bigger than the other ASLV concepts! The ALSV system would operate from a range of different airfields allowing it to achieve a wide choice of orbits at very short notice, although payload capability would have been quite limited and this is said to have been the reason why ALSV was abandoned.

A broadly similar air-launched design emerged in Russia about ten years later which was known as MAKS, and this project is described in the following chapter on Soviet space programmes. Another over-ambitious project which began at the same time as the ALSV was the USAF's Trans-Atmospheric Vehicle (TAV) programme. The aim was to design a combat aircraft capable of operating in all environments from normal altitudes to orbit. Boeing and Rockwell worked on several TAV designs and this led to a preferred Rockwell proposal for an aerospace plane that would replace the F-111. It could take-off from normal runways as a conventional aircraft, it could be boosted on a sub-orbital flight using a Shuttle Solid Rocket Booster (SRB), or the TAV might be carried into orbit within the Shuttle's payload bay. It was to be powered by one large rocket engine and two turbojets with options to reconfigure the propulsive system for different missions.

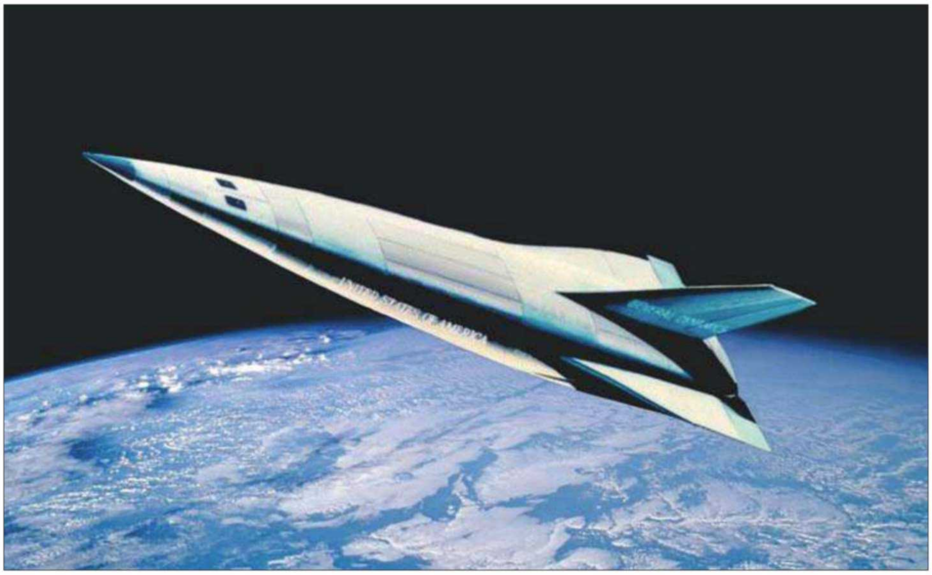
The idea of a combat vehicle with space capabilities remains very interesting, but the technical challenges of developing such a versatile piece of hardware continue to make this an unrealistic proposition at the present time. However, the USAF's quest for an independent, clandestine transatmospheric capability would go some way to explaining its general lack of enthusiasm for the Shuttle and it appears that the Copper Canyon project was sufficient to encourage substantial 'white world' funding of President Reagan's National Aerospace Plane (NASP) project.

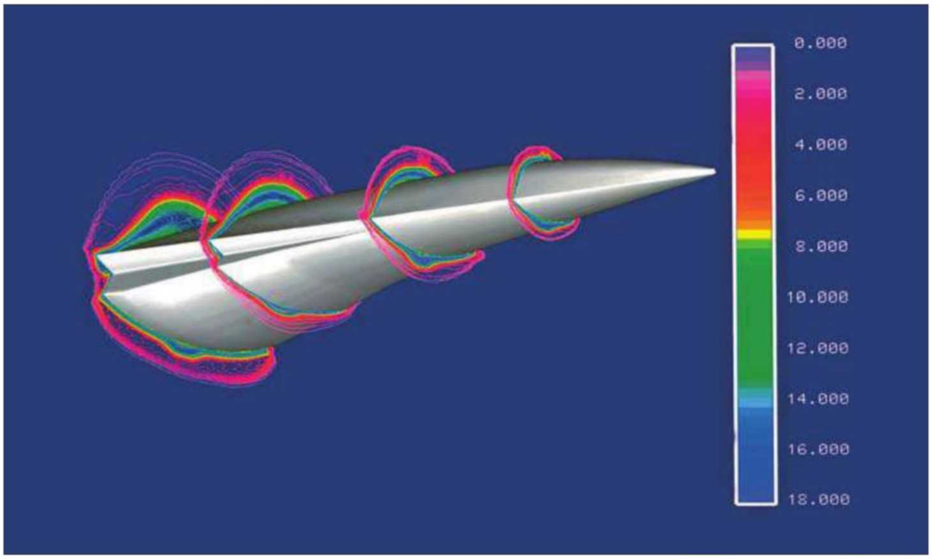
The NASP project was announced on 4th February 1986 when President Ronald Reagan made his State of the Union Address and declared that the DoD would fund development of the NASP. This would be nothing less than a fully-fledged SSTO spaceplane designed to take-off and land on a normal runway.

Although it was heavily promoted as a civil undertaking by the White House and given the title 'Orient Express', in reality the NASP was never going to be a high-speed airliner or a substitute for the Space Shuttle. Development was estimated at around $3 billion with the first prototype to be ready for flight-testing by the early 1990s. NASP would undertake specialised orbital reconnaissance missions, launch small military satellites or deliver weapons of mass destruction to far-flung parts of the world at very short notice. NASP might also have undertaken ferry missions to the future space station but that seems to have been a secondary consideration. Preparation time would be dramatically better than the 150 days required to mount a classified DoD Shuttle mission and deniable space operations might have been possible, although Russian surveillance systems have continued to improve making this increasingly difficult. That said many missions could be conducted without public knowledge if launches were undertaken from Groom Dry Lake, Nevada, or within WSMR.

Although much of the technology required for NASP was unproven, the design began to evolve rapidly. Initial studies examined a vehicle with an overall length in excess of 200ft (60m) and an airframe configured around the propulsive system. A number of proposals for propulsion were suggested with schemes for combinations of gas turbine, ramjet and rocket engines eventually giving way to a combination of turbofans and air breathing scramjet engines fuelled with slush hydrogen that could work in pure rocket mode at very high altitude. One early proposal was to circulate cryogenic fuel beneath some areas of the vehicle's skin to assist with thermal management. This would be vital to the operation of a scramjet because it was calculated that an initial performance limit would be reached at Mach 8 when the thrust became balanced with the heat generated by drag, so this extra energy contained within the fuel needed to be diverted to the engine. Aside from that, the key feature of a scramjet is its ability to draw oxygen from the atmosphere giving the spaceplane a decided weight advantage over a pure rocket system while operating in the atmosphere. Rocket propulsion would only be employed at extreme altitude when oxygen extraction was no longer possible, being engaged at about Mach 20 and accelerating the vehicle to Mach 25, which is orbital speed. Clearly the NASP's propulsive system was going to be very complex and a major technical challenge to develop.

Within a couple of years NASP had largely disappeared from public view, and it was renamed X-30A by the USAF who was now acting as the coordinating agency at Wright-Patterson AFB. A massive amount of super-



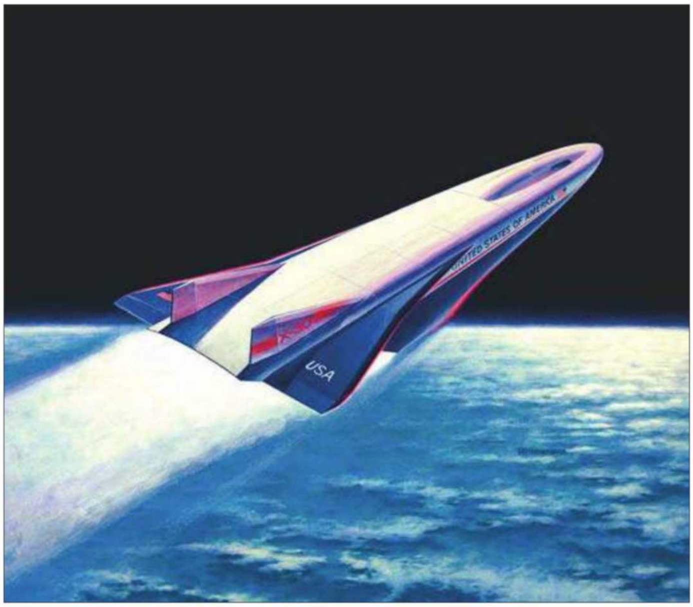


Top Left: **An early concept for the NASP.** Bill Rose/NASA

Centre left: **Early fluid dynamics profile for the NASP vehicle.** NASA

Bottom left: **Wind tunnel model of a NASP design in the TDT Tunnel at NASA Langley Research Center on 30th November 1992.** NASA

Bottom right: **A revised profile for the SSTO NASP vehicle produced as the project progressed.** NASA

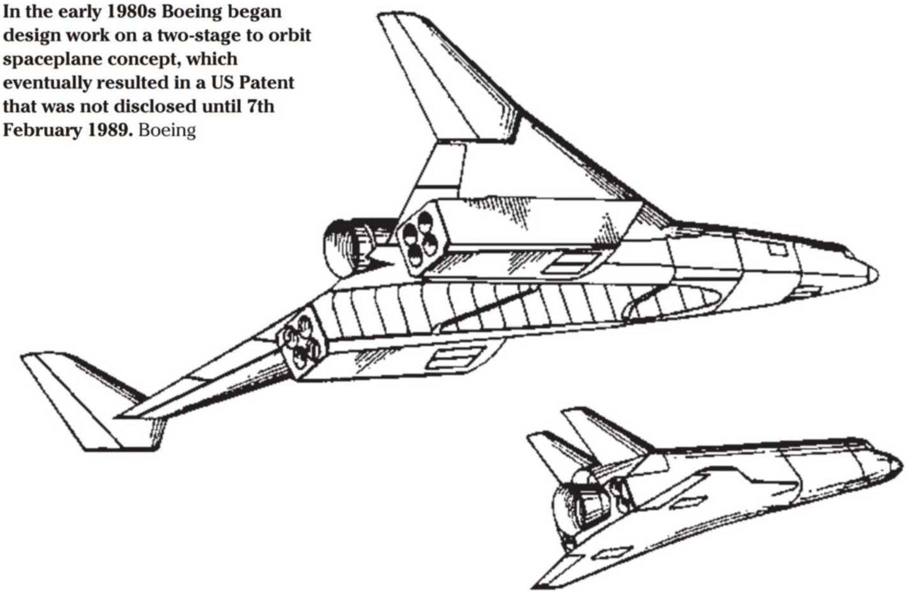


computer time was allocated to running complex aerodynamic simulations and contracts for the development of an X-30A airframe were awarded to General Dynamics, McDonnell Douglas, Rockwell, Boeing and Lockheed, who were also putting considerable effort into distancing themselves from any public discussion of hypersonic projects. The shape of the spaceplane had also altered significantly from the original highly streamlined design to a blunter-nosed configuration, which provided better compression for the ventral engine intakes. As work progressed the cost of the project began to rise steeply and it was predicted to reach $10 billion by the time flight-testing began. By the early 1990s the project was in financial difficulty and there was little prospect of the first prototype being available for another ten years. Some observers suggested that the X-30A would require another $10 to 20 billion to produce any workable hardware.

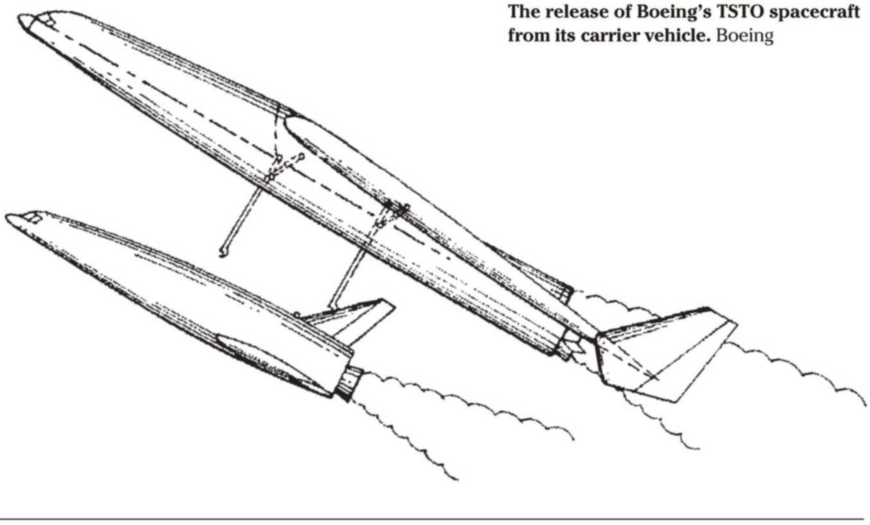
Development of the X-30A was eventually halted by the Clinton Administration, but there was increasing speculation that it had been conceived as a means of putting pressure on the Soviet Union to maintain expensive military parity while acting as the front for a secret black project using related technology. Not surprisingly there were eventual claims that this hidden project was Aurora. Said to be a two-stage orbital vehicle, this design would prove less demanding to develop than the X-30A, which may have simply been used as cover for work on advanced high-temperature materials, new fuels and the development of complex design models requiring huge amounts of supercomputer time. The technology to build a horizontal take-off and landing TSTO spaceplane had already been explored by Dornberger and Sänger with further studies on both sides of the Atlantic. While payload size would be somewhat limited with a TSTO system, the ability to operate from conventional airfields at short notice would be a major advantage over a vertical rocket launch from a large installation.

A number of USAF-sponsored studies were conducted during the early 1980s under a classified umbrella project called Science Realm. This programme considered various ideas for horizontal take-off spaceplanes and the main contractor was Boeing. It is therefore not entirely surprising that this company applied to the US Patent Office for a TSTO design on 14th October 1986. It is tempting to connect this design submission with the loss of Challenger at the beginning of that year, but available documentation shows that Boeing was preparing to apply for a patent in 1984. After this the details of the Patent (US480629) remained classified until 7th February 1989. That said the Pentagon was aware that the Russians were continuing to develop a small military spaceplane with a fairly similar specification to the X-20 and this may have helped to spur the development of a rival system.

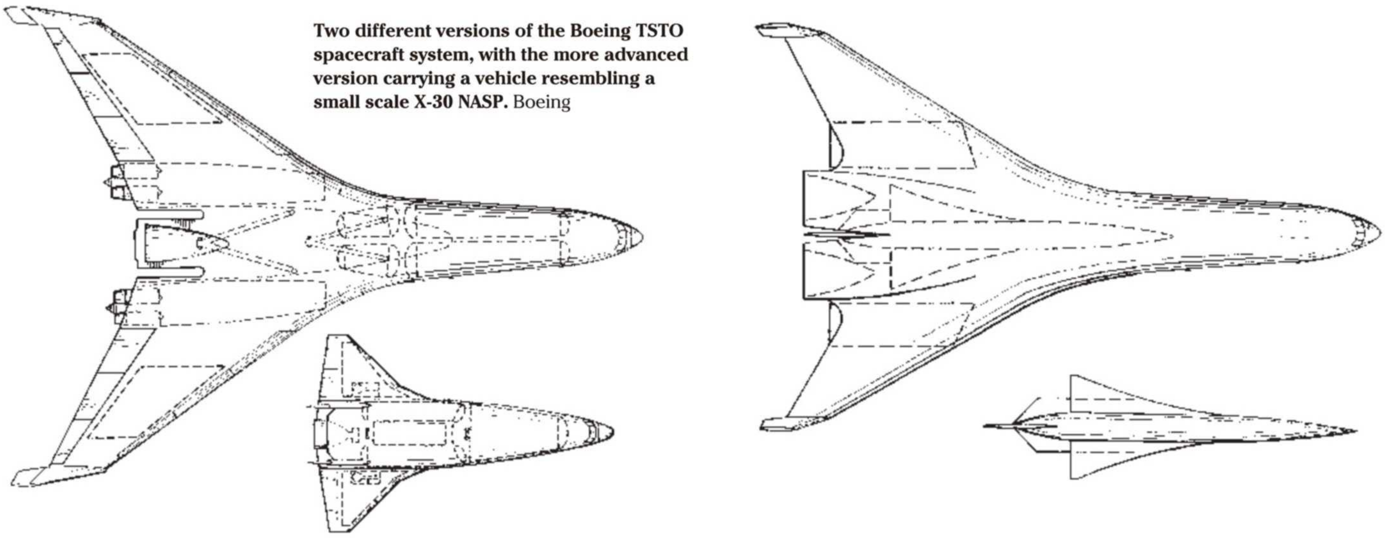
The Boeing Patent outlined a TSTO system produced by a team of Seattle engineers headed by Richard Hardy, an MIT (Massachusetts Institute of Technology) graduate who had worked on the Apollo programme and eventually became Vice President of Boeing's Military Airplane Division. The fully reusable system comprised a large two-man delta-winged carrier vehicle using air-breathing and rocket propulsion, plus a smaller two-man rocket-powered Orbiter carried semi-recessed in a contoured section below the aircraft. The launch vehicle would be powered by eight conventional afterburning gas turbine engines in two separate nacelles, with the General Electric F101-GE-102 suggested as a good choice. The jet engines would be supplemented with a single Boeing/Rockwell Space Shuttle Main Engine (SSME) using liquid oxygen and liquid hydrogen propellant. The launch vehicle would be equipped with wingtip stabilisers and fitted with a substantial three-strut multi-wheeled undercarriage with sufficient height to allow the orbiter to be rolled into position on a level surface for attachment prior to a mission. Much of this aircraft was expected to be built from composite materials that included graphite/epoxy and graphite/polyimide.



In the early 1980s Boeing began design work on a two-stage to orbit spaceplane concept, which eventually resulted in a US Patent that was not disclosed until 7th February 1989. Boeing



The release of Boeing's TSTO spacecraft from its carrier vehicle. Boeing

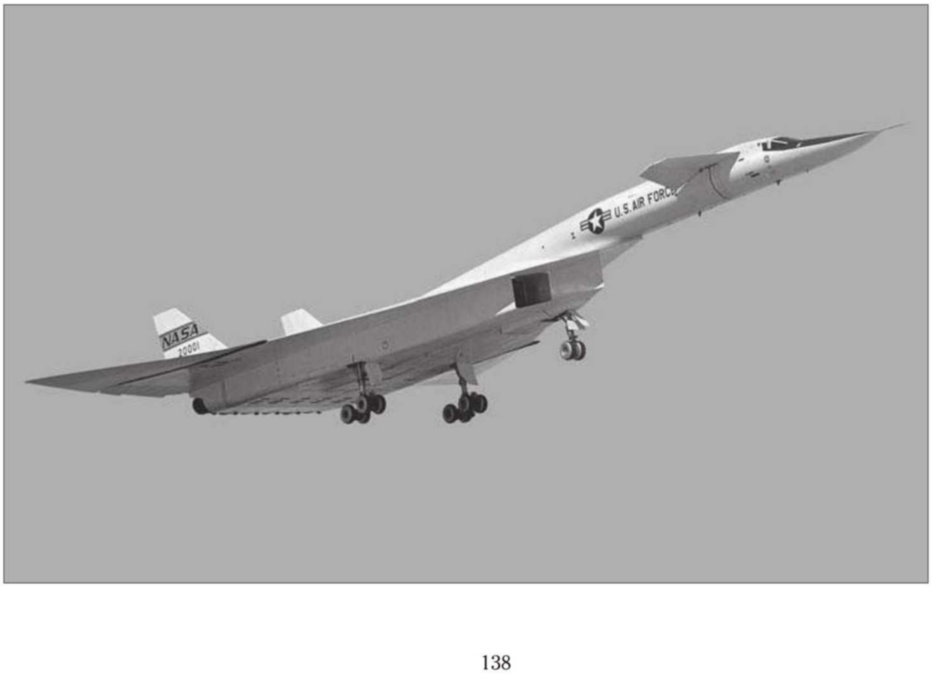


Two different versions of the Boeing TSTO spacecraft system, with the more advanced version carrying a vehicle resembling a small scale X-30 NASP. Boeing

After lift-off under jet power, the launch vehicle would engage its rocket engine and climb to an altitude of approximately 100,000ft (30,500m) and then release the orbiter at a speed of about Mach 3 to 3.5. With its main engine shut down the carrier aircraft would continue to ascend in a slow arc reaching about 125,000ft (38,000m), before it began to descend under jet engine power. After separation the Orbiter would continue to climb to LEO using a single throttleable rocket engine supplemented by four small manoeuvring engines. The preferred option for later versions of this vehicle would be scramjet/rocket propulsion and designs for a more advanced spacecraft looked surprisingly like the initial dart-shaped X-30 concept. Having released the spacecraft, the launch vehicle would return to base to make a conventional runway landing, while the orbiter would make a Shuttle-style glide landing after de-orbit. Emphasis on this design was the reduced cost of space operations and shorter preparation times. Whether this patent reflected a black programme is unknown, but it has attracted increasing attention from conspiracy buffs who believe this to be the case.

Once suggestions began to appear in print that Aurora was actually a fully reusable TSTO spacecraft, there were subsequent claims that the mothership was based on the Mach 3 XB-70A Valkyrie bomber of the early 1960s. Various names were given to this system, such as Brilliant Buzzard or Blue Eyes, but the truth is that most of this detail was simply made up to sell copy. Although there were several eyewitness reports of this mothership, many could be dismissed as bogus. However, a journalist working for CNN reported seeing an aircraft resembling the XB-70A from a location near Atlanta, Georgia and this was considered fairly credible at the time. A few weeks later a similar aircraft was sighted in the vicinity of Lockheed's Helendale radar facility and, because it coincided with a severe thunderstorm in the Groom Lake area, there was speculation that an emergency diversion had taken place.

Several uncorroborated reports followed and then there was an incident involving a near miss with a Boeing 747 belonging to United Airlines, which seemed even harder to dismiss. It was lunchtime on 5th August 1992 and the airliner had just left Los Angeles International Airport bound for London. As it reached the vicinity of George AFB, California, the 747's Traffic Alert and Collision Avoidance System (TCAS) suddenly warned the flight crew that an unknown contact was approaching at very high speed. There was no time to take evasive manoeuvres and the unidentified aircraft rocketed past, about 500 to 1,000ft (150 to 300m) below the 747 at high supersonic speed. The pilot and co-pilot both described it as having the forward fuselage of an SR-71, an overall lifting body shape and some kind of a tail. Perhaps not surprisingly, the USAF emphatically denied that one of its aircraft might have been responsible.



The experimental XB-70A Valkyrie, which may have been revived and extensively re-developed as a deep black supersonic launch vehicle capable of launching a small spaceplane. USAF

The following year a Testor model designed by the late John Andrews (who made his name with a model of an F-19A stealth fighter) appeared in stores. It was called the XR-7 Thunderdart and he produced a complementary model of the XB-70-based mothership which Testor named the SR-75 Penetrator. When the XR-7 model went on sale CBS TV Evening News carried a story about the spaceplane, with presenter Dan Rather posing the question ‘Does the United States military have a new top secret mystery plane?’ According to a story which appeared in the March 1994 issue of *Popular Science*, an arms control analyst claimed to have been shown a classified 1991 Landsat (satellite) image of Groom Lake which revealed three large triangular-shaped aircraft parked near the main runway. The analyst went on to say that ‘they are about the size of 747 airliners and remind me of the XB-70 bomber prototype from the 1960s’.

It began to look as if the USAF had secretly achieved a manned space capability, but reports of a second generation ‘Super Valkyrie’ and spaceplane started to diminish as the public’s general appetite for UFOs and black project aircraft rapidly declined towards the end of the 1990s. If there had been a highly classified spaceplane in service during the early 1990s there seemed little evidence to suppose it was still in operation. The story faded into the background until March 2006 when an article appeared in *Aviation Week & Space Technology* (AWST) magazine written by William B Scott that outlined a top-secret US TSTO spacecraft system called Blackstar.

Scott claimed that development was encouraged as a result of the Challenger Shuttle disaster in 1986 and Blackstar had been functional since the early 1990s. Apparently the launch vehicle was designated SR-3 and resembled the North American XB-70 Valkyrie Mach 3 bomber from the 1960s. SR-3 was allegedly 200ft (61m) in length and said to be very different from the XB-70A, having variable geometry canards, a blended double delta and two separate engine nacelles replacing the central propulsion unit. This would allow enough clearance for the carriage of a smaller spaceplane known as the Experimental Orbital Vehicle (XOV), which would be capable of reaching a 300-mile (482km) high orbit. The XOV is described as being half the length of the SR-3 and powered by aerospike engines using gelled fuel. Scott also said that this spaceplane was developed from an earlier unmanned test article.

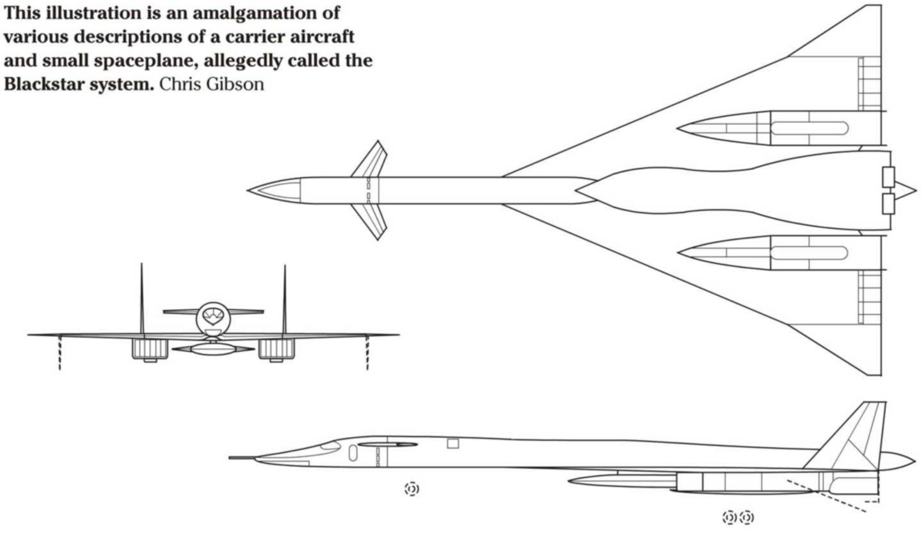
Many details of the Blackstar system have similarities to the Boeing Patent of 1989 and, presumably, the intended use of the XOV was comparable to the much earlier Boeing X-20. Funding for the Blackstar programme was allegedly made possible by diverting money from reserves allocated to the cancelled US Navy A-12A stealth attack aircraft. Boeing and Lockheed became the main contractors with the X-30A NASP project being used as a cover. Operations were conducted from Groom Dry Lake, although it is unclear what missions were flown, but Scott claims that Blackstar had been taken out of service by 2005 for reasons unknown. While this is an interesting article and AWST is a very reputable publication, there is no solid evidence to support the existence of this alleged spacecraft at the present time.

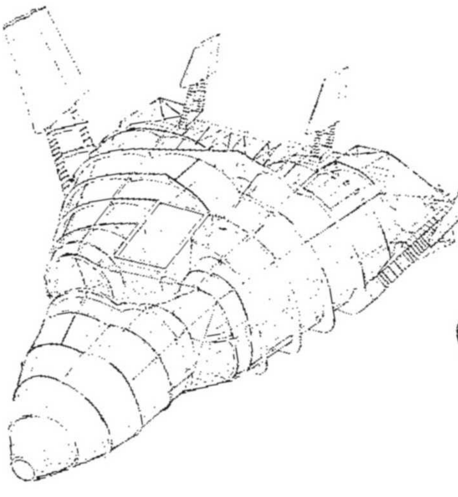
Some sightings of unusual aircraft like the North Sea triangle remain very difficult to dismiss and nobody would be too surprised if the Pentagon revealed that the USAF had developed and tested a number of high performance successors to the SR-71. A TSTO system such as Blackstar pushes the technical boundaries much further and would cost billions of dollars to develop. Its existence would be harder to conceal, but a secret spaceplane cannot be entirely dismissed as wishful thinking. During 1994 President Clinton approved plans to investigate the development of a Shuttle replacement for NASA and three completely different concepts were proposed by Lockheed Martin, McDonnell Douglas and Rockwell International.

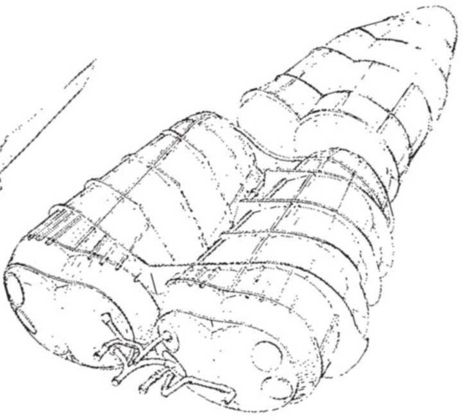
In July 1996 NASA selected Lockheed Martin to fully develop its X-33 experimental design in a deal that involved some financial investment by Lockheed Martin itself. The triangular lifting body X-33 was 66ft 11in (20.39m) in length with a nominally greater span of 67ft 11in (20.69m) and it would act as a half-sized demonstrator for an SSTO vehicle called VentureStar. The triangular X-33 would be a sub-orbital vehicle capable of about Mach 15 and was designed to demonstrate vertical take-off, ascent, re-entry, landing and a fast turn-around time requiring the minimum number of personnel. Although the USAF stated in 1998 that the VentureStar might be made available for the delivery of military payloads to LEO, the main purpose of this SSTO spacecraft was to undertake civil operations. High reliability was paramount and, although VentureStar would launch satellites and undertake ferry missions to the ISS, NASA had no expectation of using the spacecraft as a manned science platform.

Lockheed Martin announced that the prototype would be ready for testing by March 1999 and would complete fifteen test flights by December of that year. This proved (as is usually the case with advanced projects) to be very optimistic, but it raised serious questions about whether the company was drawing on experience gained in the black domain to quote such a short development period.

While the X-33 bore a superficial resemblance to Lockheed’s 1968 stage-and-a-half StarClipper Shuttle concept, it had relatively little in common with the original 186ft 6in (56.84m) long lifting body which utilised the FDL-5 and FDL-7 profiles. Internally the X-33 was filled to capacity with fuel tanks and the vehicle would be powered by more efficient aerospike technology, which had been originally considered for the Shuttle but was regarded as too immature at that time. It was planned to use two aerospike engines fuelled with liquid oxygen and liquid hydrogen for the X-33 and seven engines for the full-sized vehicle. In the event that one of the X-33’s engines failed during lift-off, there would be enough power in the remaining engine to undertake an abort runway landing after burning off most of the vehicle’s fuel. Construction of the


This illustration is an amalgamation of various descriptions of a carrier aircraft and small spaceplane, allegedly called the Blackstar system. Chris Gibson





Far left: **Early drawing of the fuel tank layout for the X-33 test vehicle which shows the maximisation of internal space for this purpose.** Lockheed Martin

Left: **Fuel tank layout for the experimental sub-orbital X-33 demonstration vehicle.** Lockheed Martin

Below left: **The aerospike engine technology developed for the X-33 is seen undergoing testing.** Lockheed Martin

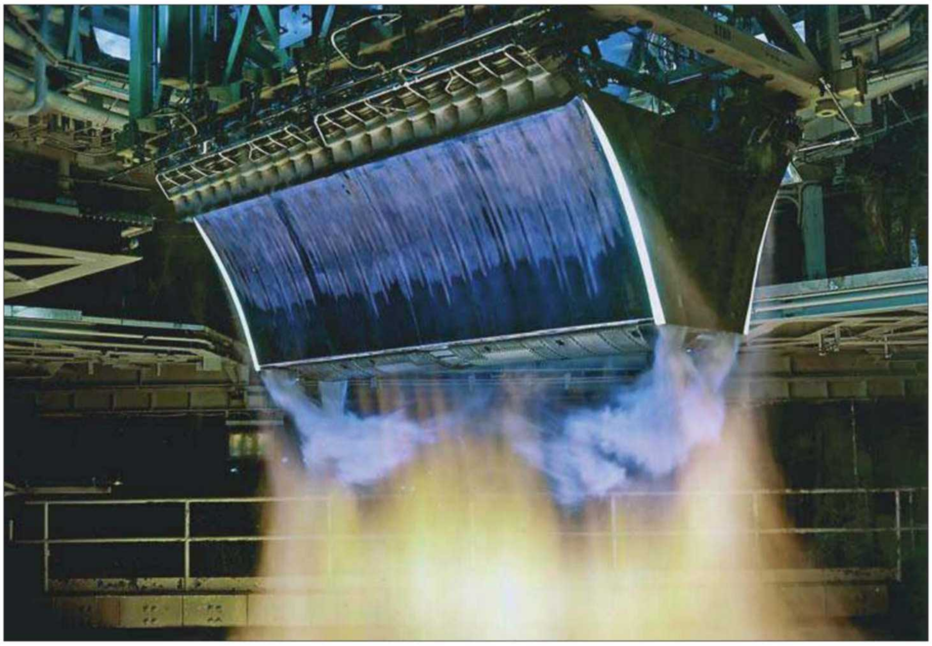
Below right: **Simulation of an X-33 test launch.** Lockheed Martin

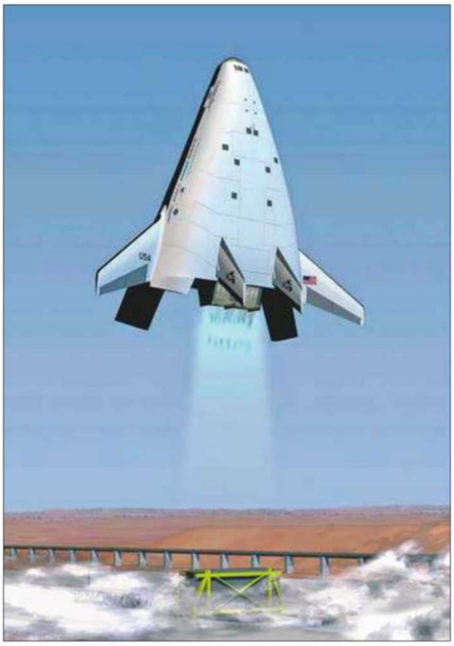
launch facility near Edwards AFB at Haystack Butte began in late 1997 and assembly of the prototype vehicle started at Lockheed Martin's Palmdale Skunk Works.

The initial test flights would have been to Silurian Dry Lake Bed about 10 miles (16km) north of Baker, California, and the second landing site was Michael Army Airfield within the Utah Test and Training Range. The third and most distant landing site chosen by NASA was Malmstrom AFB at Great Falls, Montana, with five flights scheduled to this location at speeds reaching Mach 15. However, the date to commence test flights arrived and the X-33 was not ready, with the Skunk Works reportedly having major technical difficulties fabricating the composite fuel tanks plus problems with weight management and flight stability. Then in early 2001 NASA announced that it was pulling out of the X-33 project. This came as a surprise to most outside observers because approximately 85% of the prototype had been completed and the launch facilities were ready for use. While the problems with fuel tanks were cited as the principle reason for cancellation, it appears that Lockheed Martin engineers soon resolved these difficulties.

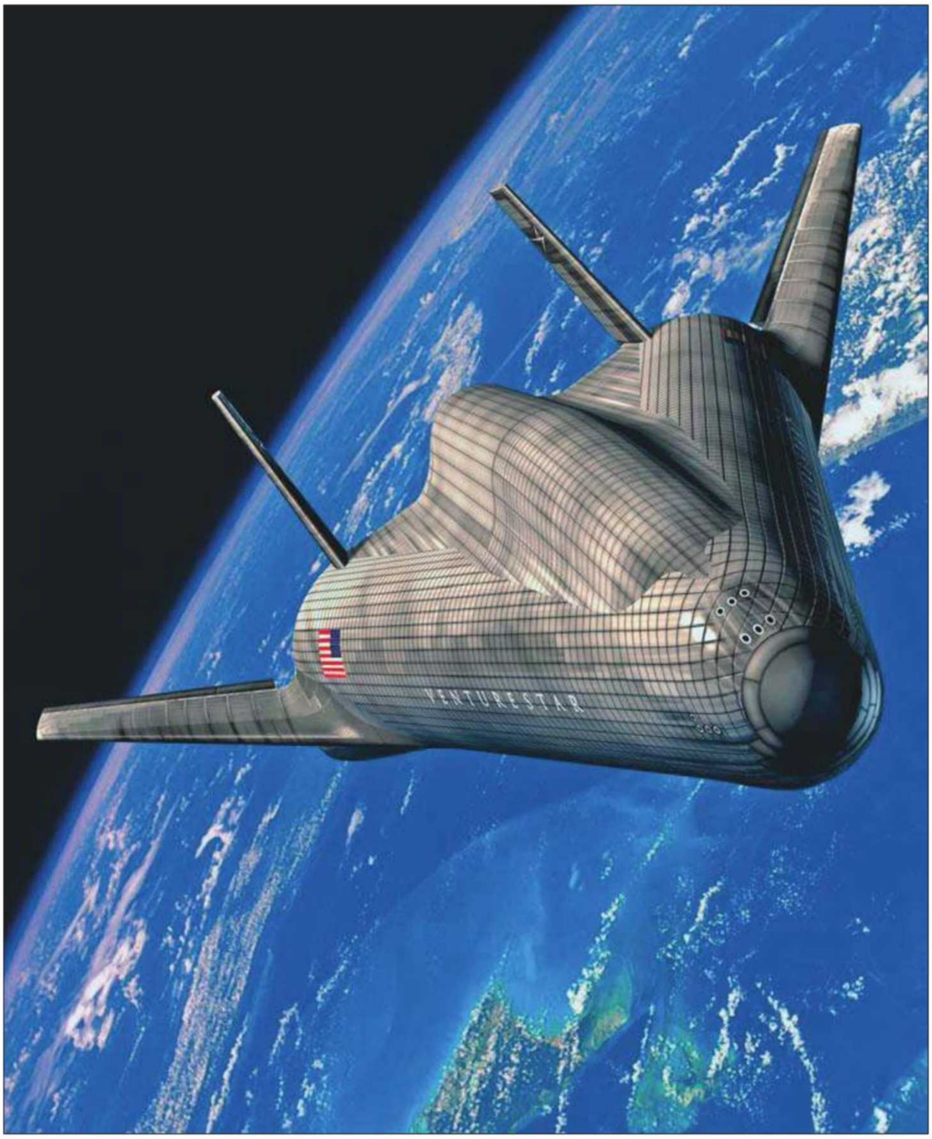
But this was a difficult time for NASA and things went from bad to worse when the Columbia Shuttle burnt up during re-entry on 1st February 2003. The loss of this spacecraft sent shockwaves through the administration and threatened to bring US manned space exploration to an end for the foreseeable future. NASA engineers determined that Columbia's destruction had been caused by a 2.5 lb (1.13kg) chunk of insulation material (described as foam), which came off the main fuel tank some eighty seconds after lift-off and impacted at high velocity against thermal tiles on the port wing causing serious damage. However, the US public continued to support the manned space programme and the Columbia Board set up after the disaster made a number of important safety recommendations for future Shuttle missions.

Boeing (who now owns the original Shuttle contractor Rockwell) reviewed the possibility of building a replacement spacecraft to be designated OV-106, and the company undertook a brief feasibility study suggesting an updated version of the Endeavour design based on original blueprints. Nevertheless, NASA now wanted a new smaller spaceplane about half the size of the Shuttle and it began the Orbital Space Plane (OSP) project to develop a craft capable of ferrying a crew of about four and modest supplies to the ISS by 2012 at the latest. NASA also required a new escape vehicle for the ISS to replace its X-38 lifting body vehicle which was cancelled on 29th April 2002 due to severe budgetary pressures caused by the ISS.





United States
NASA
LOCKHEED MARTIN
X-33



Top left: **Forward section of the X-33 airframe under construction.** Lockheed Martin

Top right: **A simulation of the triangular X-33 during a sub-orbital test flight.** Lockheed Martin

Right: **As the full-sized VentureStar design evolved it was felt necessary to improve the payload capacity and make a number of aerodynamic improvements.** Lockheed Martin

OSP was to have been launched into space using an existing booster such as the Delta 4 or Atlas 5, but the small spaceplane was finally scrapped in favour of an updated and enlarged Apollo-style capsule initially called the Crew Exploration Vehicle (CEV) but now known as Orion. This name has been previously assigned to a highly classified nuclear-powered spacecraft and the Apollo 16 Lunar Module. The Orion Spacecraft is NASA's replacement for the Shuttle and part of the new initiative for a return to the Moon, and possibly manned missions to Mars and nearby asteroids. It seems that NASA's involvement with the spaceplane is over for the foreseeable future. The USAF remains interested in hypersonic research, although plans to operate manned craft appear to have been abandoned in favour of robotic vehicles. With increasing emphasis on unmanned military aircraft there is a major programme under way to develop a fully re-usable unmanned strike vehicle capable of reaching targets up to 9,000 miles (14,500km) distant from the US mainland within 120 minutes.

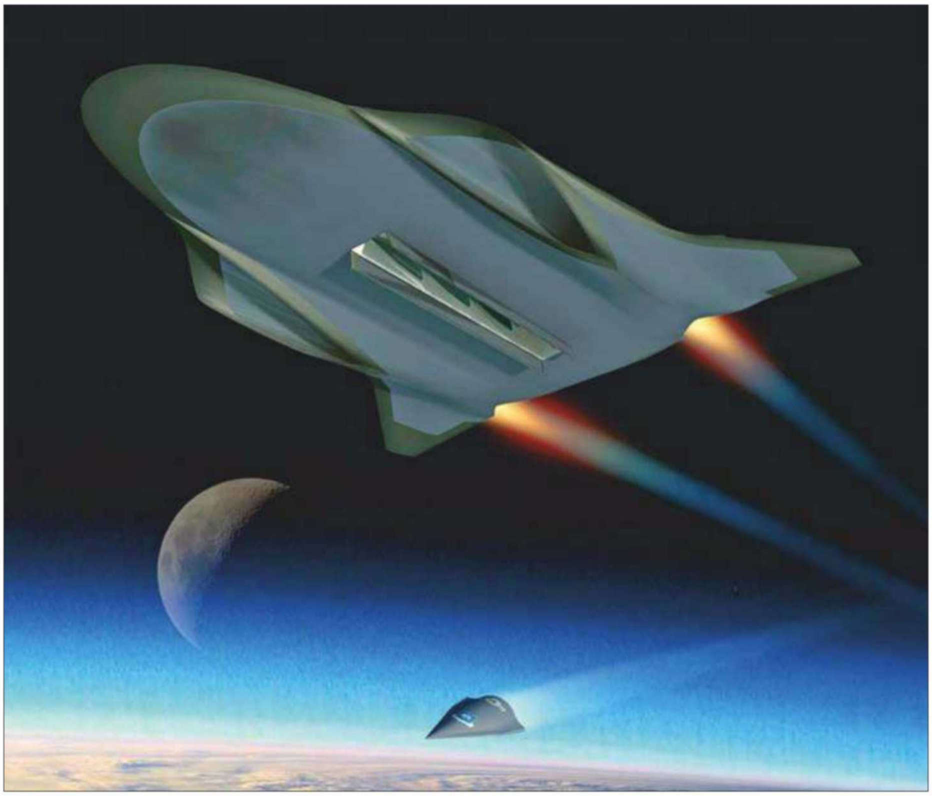
DARPA, the USAF and many contractors are currently engaged in this effort which is called Project FALCON (Force Application and Launch from CONUS – Continental USA). The aim of the programme is to build a Mach

12 craft called the Hypersonic Cruise Vehicle or HCV that flies at an altitude of 150,000ft (46,000m), mainly under autonomous control, and carries a conventional payload with an approximate weight of 12,000 lb (5,443kg). HCV is expected to enter service in 2025. Operating from an ordinary runway and utilising scramjet propulsion at high speed, the HCV will employ the original skip-glide technique pioneered by Eugen Sänger but only recently made possible due to advances in thermal management.

A spin-off from the FALCON programme is a proposed hypersonic demonstrator called Blackswift (initially designated HTV-3X) that should receive substantial funding in 2009. Developed by the Skunk Works and Pratt & Whitney, this unmanned vehicle will be about the size of an F-16, with the ability to reach Mach 6. Propulsion will be split between a gas turbine and ramjet system, with the latter becoming fully functional at about Mach 3 and running on conventional aviation fuel. Blackswift will use a normal runway for take-offs and landings.

In recent years, the move towards unmanned military vehicles has gathered momentum and small technology demonstrators like the X-37A and X-40A would suggest that the commissioning of new secret manned US space projects is unlikely in the foreseeable future.

A provisional illustration of the unmanned Falcon Hypersonic Technology Vehicle 1 (HTV-1). Falcon is a long-term project to develop unmanned hypersonic military vehicles which is shared by the USAF and DARPA. DARPA



Conceptual artwork from Lockheed Martin showing a possible future hypersonic military vehicle designed for DARPA and the USAF's Force Application and Launch from CONUS – Continental USA (FALCON) project. Lockheed Martin

AURORA HISTORY

1955	Lockheed's Skunk Works begins classified studies into a hydrogen-fuelled high-performance spyplane called Suntan, which is expected to replace the same manufacturer's U-2.
1956	The USAF gives Lockheed the 'go ahead' to build two prototype CL-400-10 Suntan spyplanes.
1959	Suntan proves to be a technological step too far and the project is scrapped. Suntan remains secret for decades and the Lockheed A-12A/SR-71 eventually takes its place in the 1960s.
1964	CIA Project Isinglass. This air-launched air-breathing Mach 4-5 spyplane is secretly studied by General Dynamics. Project cancelled in 1968.
1965	CIA Project Rheinberry, a highly classified rocket powered Mach 18 spyplane launched from a B-52 is studied by McDonnell. Rheinberry is cancelled at the same time as Isinglass.
1969	Author Joe Poyer writes a superbly researched novel called *North Cape* which concerns the flight of a top-secret hypersonic spyplane across Russia in a near future era. The technical input for this book reflects defence industry thinking in the late-1960s.
1976	Lockheed Skunk Works secretly continues development of the cancelled hypersonic X-24C under a USAF codename 'Copper Coast'. The USAF considers developing this concept into a delta-shaped successor to the SR-71.
1979	Reports circulate that Lockheed is building a Mach 4 spyplane.
1985	Pentagon P-1 Weapons document mentions the Aurora Project.
1986	President Reagan announces the 'Orient Express' spaceplane programme.
1986	Challenger Space Shuttle Accident. This had a serious impact on the USAF's spy satellite launch capability and may have encouraged the rapid advancement of a new spyplane programme.
1988	The *New York Times* claims that a 3,800mph (6,100km/h) spyplane is under development for the USAF.
1989	Unknown delta-shaped aircraft sighted above the North Sea by Chris Gibson and Graeme Winton.
1990	Lockheed SR-71 spyplane retired.
1991	Unidentified aircraft flies out of RAF Machrihanish in Scotland. Tracked by radar at Mach 3.
1991	Supersonic booms in the Los Angeles area.
1992	Unusual vapour trails sighted above Texas.
1992	Unidentified aircraft flying at 67,000ft (20,420m) above California.
1992	Dart-shaped aircraft with a lifting body appearance almost collides with Boeing 747 airliner above California. Unknown aircraft is travelling at high supersonic speed. USAF denies knowledge.
1993	X-30A 'Orient Express' spaceplane cancelled.
1994	Small number of SR-71s returned to service.
1994	Mysterious night-time accident at RAF Boscombe Down. Thought to be classified USAF spyplane.
1996	Photographic simulation of Aurora refuelling (produced by the author for a magazine article) is illegally reproduced and circulated on the Internet as factual.
1997	SR-71 quietly retired without ceremony.
1998	Sightings of triangular-shaped aircraft in the US suggest a more conventional replacement for the SR-71, possibly developed from the YF-23A fighter.
2002	Unusual 'doughnuts on a rope' contrail photographed above Horsted Keynes in England on 16th July.
2004	Classified aircraft – identified as Lockheed Test 2334 advises Albuquerque Center of supersonic flight over Florida. Returned to Area 51.
2006	*Aviation Week & Space Technology* magazine claims that a two-stage-to-orbit spaceplane has been secretly operating from Groom Dry Lake.

Chapter Five

Soviet Military Space Programmes

In the immediate aftermath of World War Two Russia made every effort to secure advanced German military technology for further development. The Germans had demonstrated the potential of long-range ballistic missiles and the Americans had produced the atomic bomb. The Cold War began soon after the Second World War had ended and massive programmes were initiated by the Kremlin to duplicate and eventually integrate both of these technologies into new offensive systems. The Americans had wasted no time in recruiting Germany's best rocket scientists and they secured large quantities of components that would allow the assembly of at least a hundred A-4 rockets in the United States. When Soviet forces arrived at Peenemünde they found much of the site in ruins. Most of the technicians had fled and there was little hardware worth recovering. However, the Red Army also occupied the huge Dora underground plant at Nordhausen and found the situation at this location somewhat better. Not surprisingly, the British were conducting an evaluation of German rocketry called Operation *Backfire* and, after interrogating scientists and recovering hardware in collaboration with the Americans, they arranged the test launchings of three captured A-4 (V-2) rockets at Cuxhaven in early October 1945. The Russians were invited to observe the third demonstration (which appears to have been largely a public relations event staged for the World's press) and amongst the Soviet delegation was an Army Colonel called Sergei Korolev.

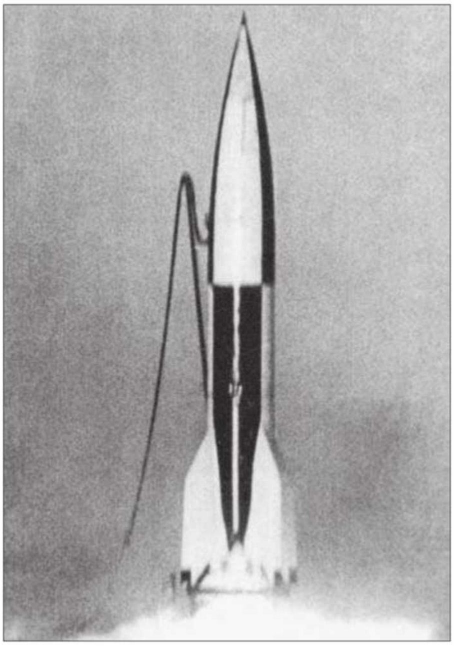
Korolev had been dispatched with an Army/KGB technical team to investigate Peenemünde, Nordhausen and Blizna in Poland and he would eventually become an equal to von Braun, taking credit for putting the first man into space. Born in Zhitomir in Ukraine, Korolev studied aeronautics at the Moscow Higher Technical School under Zhukovsky and Tupolev, graduating in 1929. By 1933 he was the chief designer of a small group of rocket enthusiasts and Korolev's designs soon attracted interest from the military. They began to fund his experiments, but the senior army officer responsible for this project was Marshal Mikhail Nikolayevich Tukhachevsky (1893-1937) who managed to make an enemy of Joseph Stalin. In 1937 Tukhachevsky was arrested for treason. He was immediately found guilty of crimes against the state and executed. Soon after this Korolev was arrested, accused of being a Trotskyite, found guilty of treason and sentenced to ten years in a Siberian labour camp. However, towards the end of 1940 Stalin realised that the USSR urgently needed scientists to exploit rocket technology and, following a personal request to the leadership from Andrei Nikolayevich Tupolev (1888-1972) who had also been sent to the Gulag, Korolev was returned to Moscow.

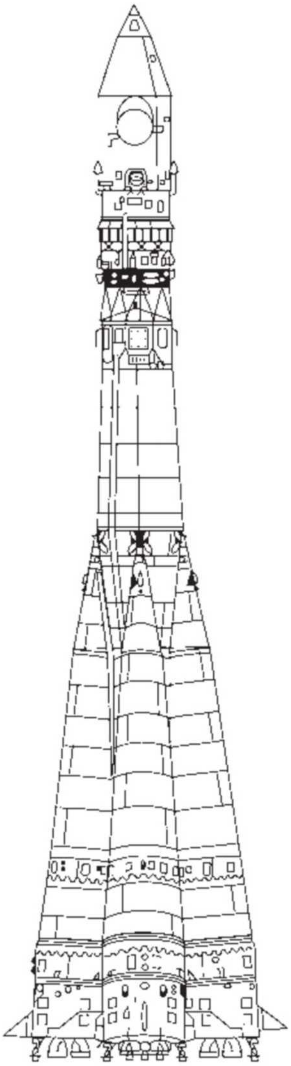
Having been released from his sentence and given a commission in the Army, Korolev was eventually sent west with a specialist team to see what could be salvaged in occupied Germany. Nordhausen had been handed over to the Russians on 1st July 1945 by the US Army and it was immediately re-named 'Zentralwerk' (for Central Works). Although the Americans had taken whatever they could, this facility turned out to be an invaluable acquisition. On 9th September 1945 the Russians managed to secure the services of former Peenemünde scientist Helmut Gröttrup (1916-1981) who had worked with von Braun and was primarily responsible for the A-4's flight control system. He recruited a number of experienced German engineers and by mid-1946 they had re-established the Nordhausen assembly line, drawing on the huge stockpile of components that remained in the tunnels.

This photograph taken in early 1946 shows Artillery Colonel Georgiy Tyulin (left) and Sergei Korolev during A-4 recovery operations in Germany. via NASA

Gröttrup's team completed a number of A-4 rockets, but then on 22nd October 1946 the facility was unexpectedly shut down and the entire workforce was loaded onto a train at Kleinbodungen and transported to Moscow. Within weeks 'Zentralwerk' had been completely stripped and it remained unoccupied until the summer of 1948 when Red Army engineers blew up the entrances and sealed off the underground factory. Korolev now headed the Russian rocket programme and, although he recognised the considerable advances made in Germany, he believed that his scientists were just as capable as the Germans and, given enough time, could improve on the original technology. Test launches of post-war A-4 rockets began on 18th October 1947 at the newly-opened Kapustin Yar test range, which was located between Volgograd and Astrakan. Another test site was under construction at Baikonur in Kasahkstan and these facilities would remain hidden from the West for many years. Launches of German rockets gave way to Russian copies and the R-1 (SS-1 – NATO codename *Scunner*), which became Russia's first military ballistic missile, completed its initial test flight at Kapustin Yar on the 10th October 1948.

Korolev's engineering team was making good progress and it is evident that the Germans were being well looked after in return for their expertise. Nevertheless, Soviet industry was old-fashioned and many years behind the West, and this had a serious effect on the production of missiles for military use. The first small batch of R-1s was supplied to the





23rd Army Brigade (BON RVGK) in December 1951 and fitted with high explosive warheads similar to the original German design. One variant that was considered but not built was a sea-launched version of the weapon based on wartime German proposals for a submarine-towed capsule.

The next major design was a stretched version of the A-4 with a longer range and greater payload which was first tested at Kapustin Yar on 30th September 1949. This missile represented a logical development of the A-4 and German engineers had already considered a similar configuration. Designated R-2 (SS-2 NATO codename *Sibling*), it was approximately 50% heavier than the standard A-4 and had a range of approximately 370 miles (595km). It had an overall length of 68ft 10in (21m) and a core diameter of 5ft 6in (1.7m), a launch mass of 43,281 lb (19,632kg) and a payload of 1,119 lb (508kg). The R-2 carried a high-explosive warhead but was incapable of lifting a first-generation Russian nuclear device which was heavy, bulky and unsuitable for missile delivery. However, in addition to the high explosive, versions were built to carry Sarin nerve agent or a very nasty radiological payload. In November 1951 the Red Army accepted the R-2 for service entry, which began in 1953.

The R-3 and R-4 were little more than design studies, but work was already under way to produce a reliable medium-range ballistic missile with the ability to deliver a substantial nuclear warhead to most strategic targets in Western Europe. This new weapon became the R-5 (SS-3 NATO codename *Shyster*), it was road transportable and offered a range of 745 miles (1,200km). The R-3 represented a significant improvement over earlier missiles in having a separable re-entry vehicle and relatively advanced inertial guidance which provided good accuracy for that time. On 10th April 1954 the Kremlin approved the development of the R-5M and this led to the eventual testing of a missile with a live 300 kiloton nuclear warhead on 2nd February 1956. The launch went exactly as planned and operational status of the R-5M was achieved a few months later.

Stalin died in 1953 and, with the change of mood under Khrushchev's leadership, Korolev took the opportunity to submit plans to the Politburo for an Earth satellite. He followed this in 1955 with proposals to modify an R-2 missile to launch a capsule containing a cosmonaut on a sub-orbital flight into space. The compact capsule would have been fitted with retro rockets, a parachute and struts for landing purposes. Reminiscent of Megaroc, it is conceivable that the Russians could have put a man into space several years earlier if this proposal had gone ahead. Not surprisingly the Kremlin rejected the plan,

Top left: **Soviet soldiers pose next to a captured German V-2 which was shipped to the Soviet Union from Germany in 1946.** NPO Mash

Top right: **A captured German V-2 is test launched by the Soviet Army.** NPO Mash

Left: **The Soviet Vostok rocket developed from the original launch vehicle which placed Sputnik I in orbit during 1957. Designed for use as an ICBM, its use was limited in this role, but the rocket went on to become the world's most successful and reliable launch vehicle.** NASA although the idea of a man in space continued to generate official interest. Korolev was soon working a large liquid-fuelled multistage ICBM designated R-7 (SS-7 NATO codename *Sapwood*), which proved unsatisfactory as a weapon but was perfect for launching spacecraft. The R-7 eventually became the A-1 and was used to place the Sputnik satellite into orbit on the 4th October 1957 and to launch Yuri Gagarin into space onboard Vostok-1 during 12th April 1961.

Buran and Burya

One particular German World War Two military project that captured the imagination of the Soviet leadership was the Sänger-Bredt spaceplane described in an earlier chapter. Stalin approved plans to kidnap the Sängers and to reproduce the spaceplane, but neither of these schemes came to anything and Soviet scientists soon realised that the space bomber was too advanced to be built with existing technology – it belonged to a future era. The Russians also experimented with several aircraft based on the prototype German DFS 346 supersonic rocketplane, also discussed in a previous chapter. Although these tests ended in 1951, the Russians did not entirely abandon high performance military rocketplanes and concepts continued to be studied by Korolev's engineers. Between 1951 and 1953 Korolev's Opytnoe Konstructorskoe Byuro (Experimental Design Bureau) No 1 (OKB-1) produced various ideas for a cutting-edge long-range cruise missile designated EKR-1. This mirrored research taking place in the United States with the Hermes ramjet experiments at WSMR that led to the Navaho missile. EKR-1 had potential but needed considerable refinement, and because Korolev's bureau was heavily involved with the development of ICBMs it was decided to re-allocate the project elsewhere.

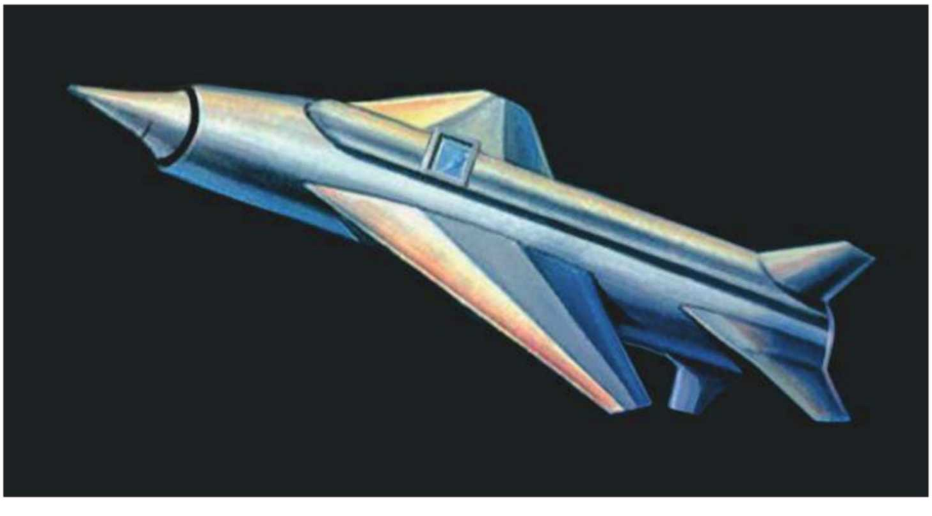
On 20th May 1954 OKB-23, run by Vladimir Mikhailovich Myasishchev (1902-1978), was officially requested to proceed with the development of EKR-1, which was to be capable of delivering a nuclear warhead over an intercontinental distance of at least 5,280 miles (8,500km). The missile would cruise at a speed in excess of Mach 3 and would provide a rapid response to any US nuclear bomber attack on the homeland. OKB-23 assigned the designation M-42 to the missile, which also received the name Buran (Snowstorm) that was eventually re-used for the Soviet Space Shuttle. The booster stage was designated M-41. At exactly the same time OKB-301 controlled by Semyon Alekseyevich Lavochkin (1900-1960) was requested to develop a very similar missile called the La-350 Burya (Storm), which was designed to the same basic specification.

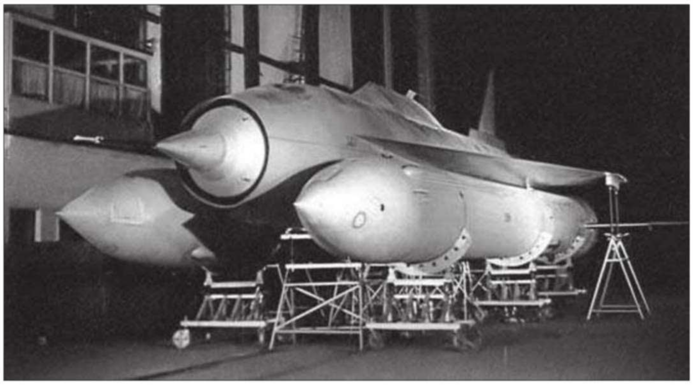
Both missiles started life as aerodynamic studies by the Central Hydrodynamics Institute (TsAGI) and featured a mid-wing with 70° of sweep. Other common features included the Bondaryuk RD-020 ramjet engine running on standard jet fuel, a shock cone intake at the nose and the same astro-navigation and guidance systems mounted in a dorsal spine with quartz windows for the star-tracking sensor. However, there were some notable differences between the two projects and the Myasishchev vehicle was slightly bigger to allow it to carry a larger thermonuclear warhead weighing 7,700 lb (3,500kg) compared to the La-350's lower yield design weighing 4,630 lb (2,100kg). Much of the initial design for the M-42 had been completed by the time OKB-23 was requested to proceed with full development. The overall length of this two-stage vehicle was 78ft 9in (24m) (some sources say it was slightly longer), span was 38ft (11.6m) and launch mass 275,577 lb (125,000kg). The four rocket engines for the M-41 first stage were built by Glushko and fuelled with nitric acid and kerosene, burning for fifty seconds with an Isp of 254 sec.

The Lavochkin La-350 was somewhat smaller with an overall length of 65ft 3in (19.9m) and a launch mass of 211,643 lb (96,000kg). The first-stage booster for the La-350 also differed considerably and comprised two Burya S2.1150 rockets fuelled with nitric acid and amine. Cruise speed may have been slightly higher, but it is probable that the range was a little less than for the M-42. Although work on the M-42 began first, the initial La-350 prototype was completed in spring 1957 and tested on some date between July and September of that year. According to many reports the vehicle exploded soon after launch, but this now appears to be a false story. In 1992 several engineers who had worked on the La-350 revealed an entirely different account of the trials which was supported by photographic evidence. It is now clear that five long-range test flights were undertaken between June 1957 and April 1958, the launches taking place at the Volga River Delta. These flights were all very successful with four being flown at night for security reasons and the fifth in daylight to validate the star tracking system in bright light.

Above: **Best known for his aircraft designs, Dr Vladimir Myasishchev also worked on several classified spacecraft programmes during the 1950s.** Bill Rose

Below: **Artist's illustration of a Myasishchev M-42 Buran ramjet-powered missile after separation from the four booster rockets. An M-42 was prepared for launch in late 1957, but the project was cancelled before the flight took place.** Bill Rose





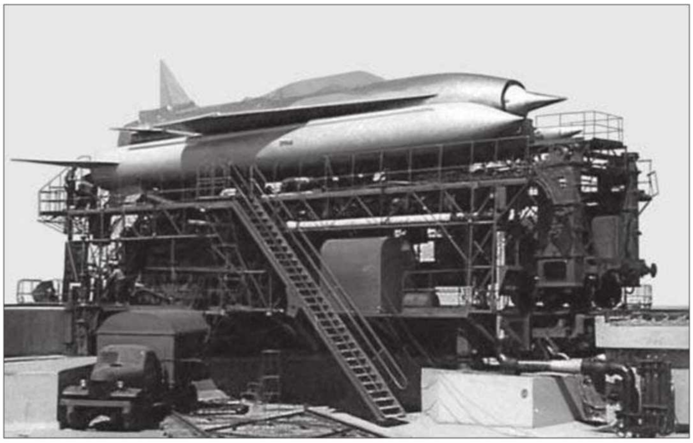
Left: **One of the several Lavochkin La-350 prototypes which appears to have various minor design differences, suggesting that changes were made during development.** Lavochkin

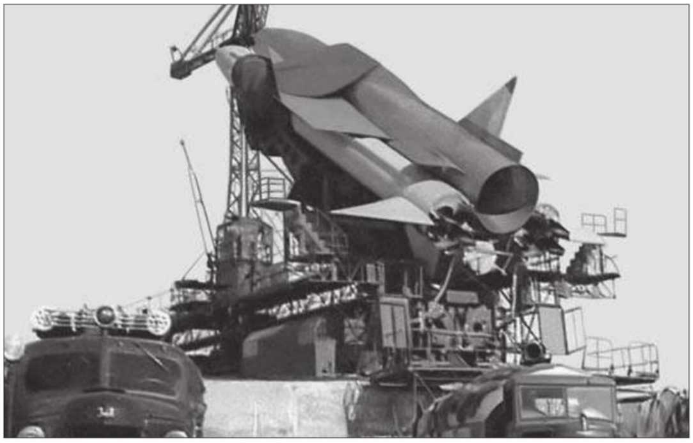
Lower left: **A clipped wing version of the La-350 partly elevated on its launch platform.** Lavochkin

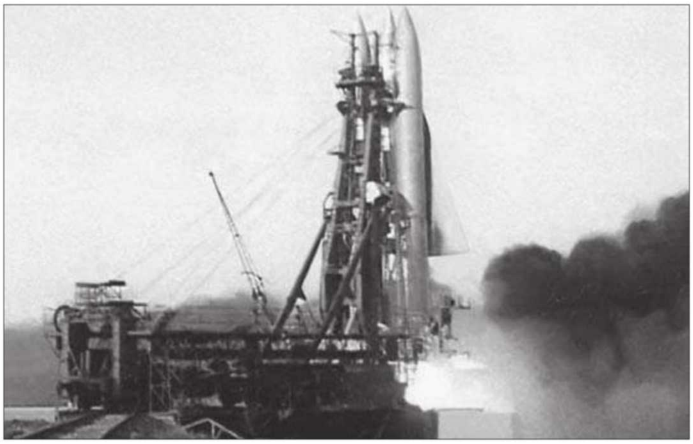
Lower right: **La-350 on its launch platform with the star tracking system covered by a tarpaulin.** Lavochkin

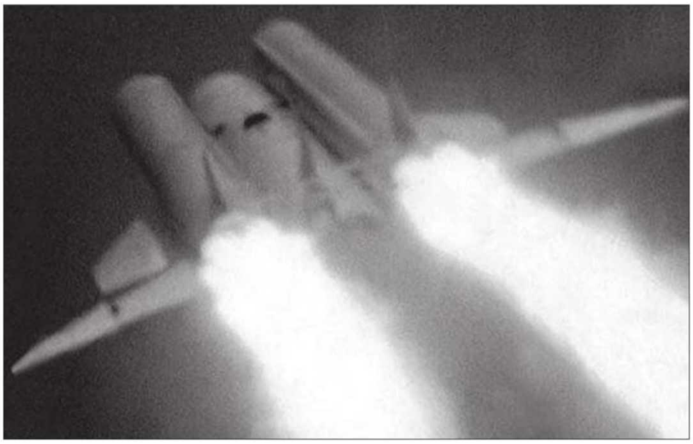
Bottom left: **An La-350 prototype is launched during the late 1950s. Note the triangular wing shape.** Lavochkin

Bottom right: **An La-350 lifts-off under the power of its two rocket boosters.** Lavochkin









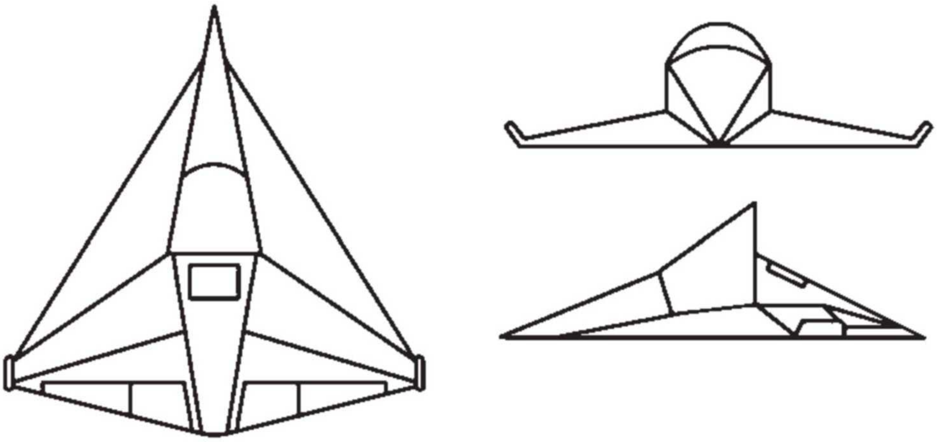
It has been reported that the M-42 was being prepared for testing in November 1957 when the project was cancelled, with official interest switching to ICBM development. I cannot guarantee that these details are entirely accurate but there is no reason to believe that the prototype M-42 Buran made any flights, even if La-350 testing continued into the following year. Myasishchev attempted to secure official approval to develop an air-launched vehicle which was designated M-44. Based on the M-42 cruise stage of the Buran, it would be launched at supersonic speed from the prototype M-52 bomber and the missile was expected to achieve hypersonic performance.

The M-44 never progressed beyond the drawing board but new technology developed during the M-42/44 and La-350 projects found further employment later on. There were also plans to build manned versions of the M-42, M-44 and La-350 to gain experience of high-speed flight at extreme altitudes. On the manned Myasishchev vehicle the pilot would eject at the end of the mission and descend by parachute. Lavochkin hoped to develop the La-350 in a similar manner but intended that his design should make runway landings and be re-usable.

The Early Spaceplanes

In late 1956 Myasishchev undertook a series of design studies for a very small manned spaceplane, generally described as having a porpoise shape, which was intended to be launched using an R-7 rocket. Bearing certain similarities to the Armstrong Whitworth waverider, this spacecraft was 11ft 6in (3.5m) long, had a span of 12ft 6in (3.8m) and a mass of 2,006 lb (1,000kg).

Myasishchev was a personal friend of Korolev and they exchanged ideas about this study, which generated interest within the Soviet Ministry of Defence where concerns were growing about the US programme to



The small VKA (Aerospace Vehicle) designed in 1957 by Myasishchev which would have been launched by an R-7 rocket. Bill Rose

The initial design for a small one-man spaceplane, which was developed by Myasishchev's design bureau in response to request by the Soviet Air Force in 1958. Bill Rose

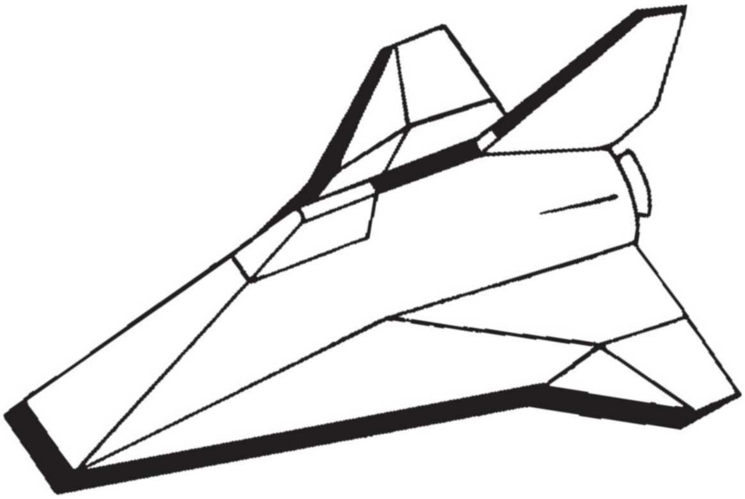
develop a manned rocket bomber. As a consequence the Soviet Air Force approved the rapid development of a spacecraft capable of military operations that was based on this early design work. During Phase One of the project the initial test vehicle would be launched using the first stage of an R-7 booster and it would reach Mach 5 to 6 at an altitude of 50 to 60 miles (80 to 100km). In Phase Two of the programme a speed of at least Mach 10 would be attained at an altitude of 62 to 93 miles (100 to 150km); this would use an R-7 with a second stage.

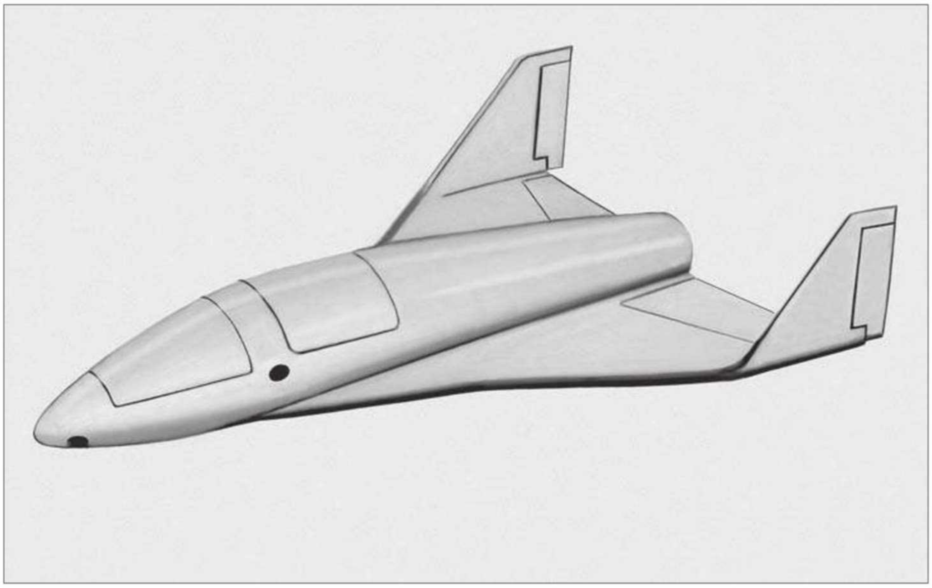
Myasishchev's OKB-23 was located at Fili near Moscow and was generally considered to be the most advanced and best run aerospace development organisation in Russia, so in 1958 it was instructed to develop a small spaceplane known as the Voduzhno Kosmicheskiye Apparat – Aerospace Vehicle (VKA). It was common Soviet practice to assign a parallel programme to another design bureau using the same initial specification and this went to OKB-256 run by Pavel Vladimirovich Tsybin (1905-1992). He assigned the name Gliding Spacecraft (PKA) to the project and work officially began at OKB-256 on 17th May 1959 after Tsybin had signed the development contract. It was also decided that spacecraft work by both Design Bureaux would be co-ordinated by Korolev at OKB-1.

The first Myasishchev VKA design was known within the bureau as Article-48, or later M-48. The compact one-man spacecraft had a faceted appearance rather like the forward section of the F-117A stealth interdictor. This wedge-shaped delta-winged vehicle was equipped with a single tail fin and the cockpit was centrally located. M-48 had an overall length of 30ft 10in (9.4m) and a span of 24ft 8in (7.7m), a launch mass of 7,700 lb (3,500kg) and a payload capability of 1,544 lb (700kg). A small liquid-fuel rocket engine would provide a delta v of 320ft/sec (100m/s) and the vehicle would be equipped with a reaction control system. Myasishchev's chief designer Gennady Dermichev was appointed to head the spaceplane project with Evgeny Kulaga taking responsibility for airframe development. Many distinguished scientists became involved with VKA including Professor Mstislav Keldysh who had worked on an unsuccessful post-war project to duplicate the Sänger-Bredt spaceplane.

Various innovative technologies were considered for cooling key areas including liquid metal, columbium and ceramic panels. The airframe was built from aluminium and titanium and it appears that the vehicle utilised the Nonweiler waveriding concept. The life support system was similar to that used in Vostok capsules and the pilot would be housed in an ejection capsule designed to operate from sea level to vacuum conditions, although it was primarily intended for emergency use during a lift-off failure. Launched with an R-7 rocket, it would eventually be possible to attain a 250-mile (400km) high orbit with the potential for a twenty-four-hour mission. After de-orbit and a glide descent, it was proposed to use a jet engine for enhanced manoeuvring and to permit a controlled landing. However, it was finally decided that it was safer if the pilot ejected at about 15,000ft (4,572m), leaving the VKA to make an automated landing using deployable skids. The VKA would then be available for refurbishment and re-use. Although the VKA was a military project, it is not clear if the spacecraft was simply seen as a development platform for a more advanced vehicle or if it was considered for ASAT and reconnaissance operations.

A fully functional prototype was completed but a review of the project in late 1960 suggested numerous revisions and Myasishchev began work on a significantly different vehicle called VKA-2. The one-man VKA-2 differed considerably from its predecessor and had a more streamlined appearance. It was a lifting body with stabilising fins at the wingtips, it had an overall length of 29ft 6in (9m), a span of 24ft 9in (7.5m) and a similar weight and payload capacity to VKA-1.





The more efficient VKA-23 Design 2 produced by Myasishchev which followed a major re-evaluation of the initial faceted waveriding configuration. Bill Rose

Tsybin's OKB-256 was making good progress with its alternative PKA spacecraft which was to be launched into orbit using the R-7. PKA had a length of 32ft (9.75m), a span of 26ft (7.92m) and a lift-off mass of 9,900 lb (4,490kg). It was equipped with liquid-fuel rocket propulsion for on-orbit manoeuvring and de-orbit braking plus an attitude control system. Life support was similar to the Myasishchev designs and the PKA was fitted with an ejector seat that would be oriented in three different positions during the mission. Much of the airframe was built from high-grade steel and there was a unique liquid-lithium closed-cycle cooling system to regulate the temperature in the leading edges. The additional weight of this spacecraft would have restricted the orbital altitude attainable with the R-7 booster but the PKA had the same endurance capability as OKB-23's alternative designs.

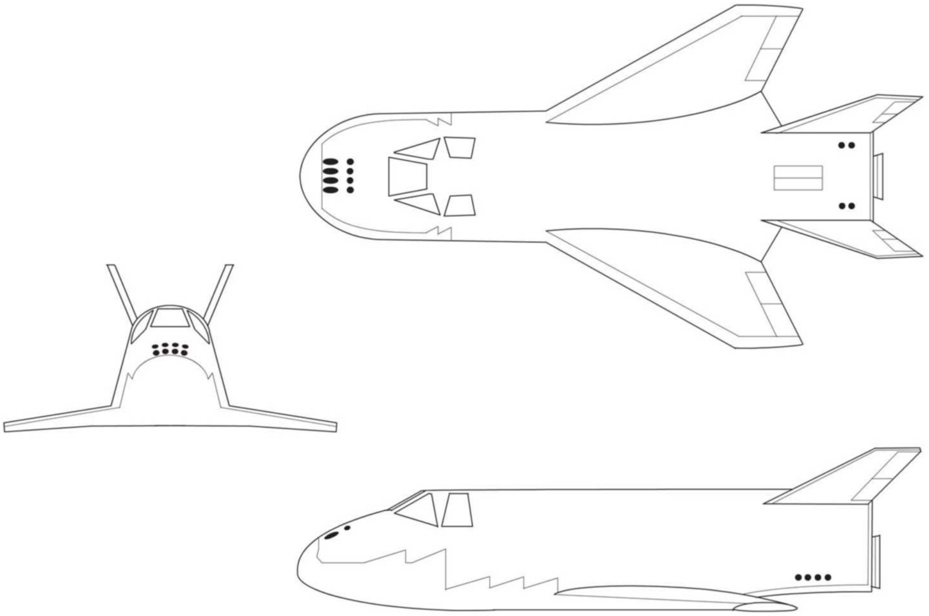
Vladimir Chelomei who headed the elite OKB-52 Bureau. NPO Mash

The overall shape of the PKA might be described as a slightly flattened streamlined oval, with four tail fins and short wings which remained folded during launch. After re-entry PKA would unfold its wings and glide to the landing site to allow the pilot (after jettisoning the lower tail fin) to make a conventional runway landing using skids. Unfortunately for Tsybin the bureau was under considerable scrutiny from the Ministry of Defence and it was clear that many technical issues remained unresolved, despite the fact that a prototype had been completed. In a dramatic and unexpected re-structuring, OKB-256 was closed down and all members of its staff, including Tsybin, were transferred to Myasishchev's OKB-23 where work on VKA-2 continued. Some of these scientists and engineers did proceed with the VKA-2 but OKB-23 was also under threat and in autumn 1960 it too was closed down on the orders of Khrushchev. Most of the scientists and technicians were then moved to OKB-52 and Tsybin went to work for Korolev at OKB-1. Although three prototypes had been built, the VKA project was at an end and all of the hardware and documentation was moved to OKB-52, where a new spaceplane programme was under way. Having gone to work for Korolev, Tsybin became involved with the Soyuz series of spacecraft and later the Buran Space Shuttle. Myasishchev was given a position with OKB-52, but finally left to become director of the Central Hydrodynamics Institute (TsAGI).

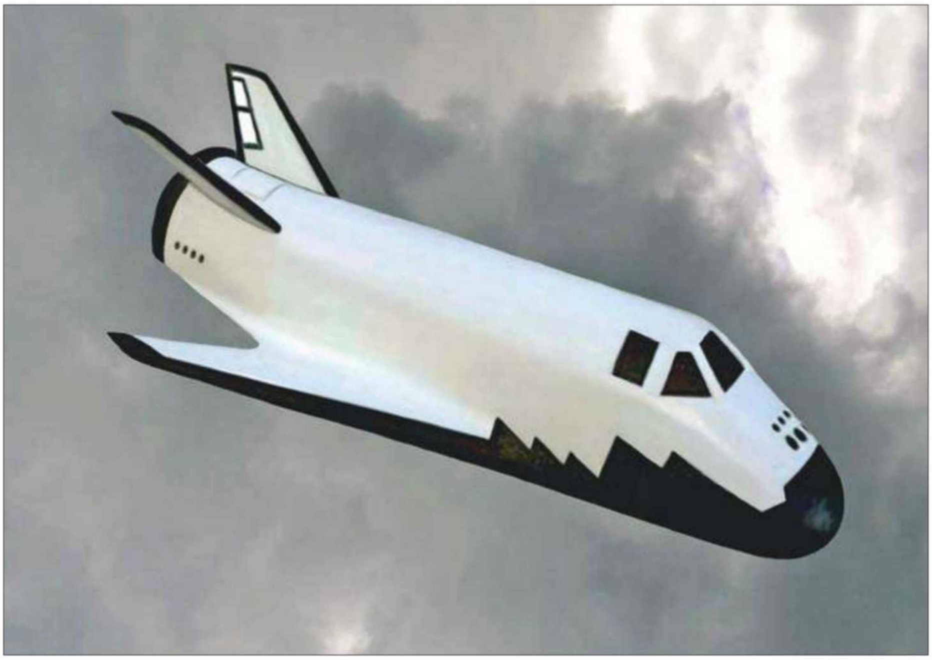
OKB-52 had been established in 1955 for the purpose of missile and rocket development. The bureau was headed by Vladimir Nikolayevich Chelomei (1914-1984) who was a brilliant engineer and also very well connected with the Party leadership. In fact, one of his deputies was the Chairman's son, Sergei Khrushchev. In 1959 Chelomei had been appointed as Chief Constructor of Aviation Equipment and he wanted to make his mark by building an equivalent to the American Dyna-Soar. He submitted a series of proposals to the Central Committee for a two-man Raketoplan (Rocketplane) that was capable of intercepting American satellites and returning from space to make a conventional runway landing. Missions would last for up to twenty-four hours and there would be scope for launching space-to-ground weapons. In early 1960 Chelomei visited Chairman Khrushchev in the Crimea and described a series of ambitious military space projects, suggesting that OKB-52 would need the facilities of a large and well run support facility. An obvious choice was the Myasishchev bureau, which was struggling with its spaceplane programme and had no major forthcoming production work in its schedules.

On 23rd June 1960 Decree 715-296 was issued which outlined the Soviet Union's military space requirements for the late 1960s and paved the way for OKB-52 to begin initial studies for a rocket-launched re-usable spaceplane. Progress with the study was rapid and on 3rd October 1960 Chelomei took full control of Myasishchev's OKB-23. Comrade Chelomei's authority was growing in leaps and bounds because he now employed all of the scientists and engineers who had worked on the VKA projects and had all their research documentation, blueprints and hardware under his control. It is unclear if links were maintained with OKB-1, although it seems likely that Korolev was involved in the new project to some extent. Chelomei's Raketoplan project got moving on 1st November 1960 and it was hoped within a year to complete an unmanned test vehicle called the R-1.

If the programme progressed without too many problems, a piloted vehicle called R-2 would follow, with the first launch taking place between 1963 and 1965. Operational examples of Raketoplan would be available in the late 1960s. The initial specification for the manned vehicle proposed a length of 32ft



The Raketoplan was a small spaceplane that emerged from a series of studies conducted under the direction of Chelomei at OKB-52. Chris Gibson



Artwork showing the Chelomei Raketoplan after re-entry. Bill Rose

(9.75m), a span of 13ft 6in (4.11m) and a mass of approximately 14,000 lb (6,350kg). A Proton rocket would be used to boost the Raketoplan into a 186-mile (300km) orbit. Options for one and two crew members appear to have been considered and, like all previous Soviet spaceplane designs, the cosmonauts would be provided with ejector seats.

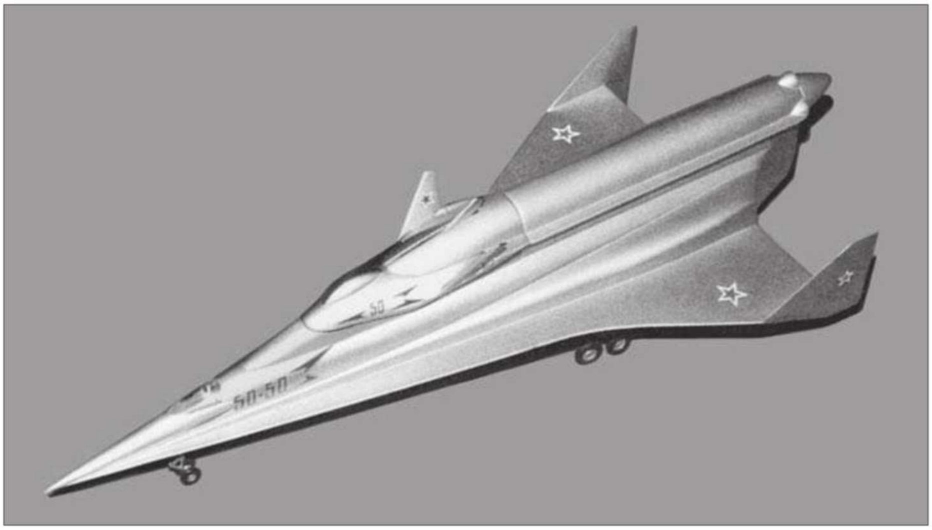
The early design utilised an umbrella-shaped air brake to slow descent before swing-out wings were deployed to assist the glide to a runway landing, although both these features underwent considerable revision and the wings became fixed. As it evolved the Raketoplan started to resemble some of the early proposals made for the US Space Shuttle. It had a mini shuttle body, swept wings, two tail fins and a rear-mounted module. An unmanned scale model with a mass of 3,858 lb (1,750kg) was ready for testing by early October 1961 and it was transported to Kapustin Yar for launch using an adapted R-12 rocket. Given the name MP-1, this test vehicle was fitted with an oblique conical heat shield and extendible tail brakes. During the flight, data would be returned to the ground and three parachutes would be deployed at the end of the mission to facilitate the vehicle's recovery. On 27th December 1961 MP-1 was carried on a sub-orbital flight which reached an altitude of 250 miles (405km) before making a re-entry and final landing near Lake Balkhash, some 1,168 miles (1,880km) downrange.

The flight was judged to have been a success but several modifications were made to the design and incorporated into a second test vehicle called the M-12. This included a change to the braking surfaces and a sophisticated attitude control system. M-12 was launched on a sub-orbital test flight on 21st March 1963 and, although the flight went well, the heat shield failed and the vehicle broke up during re-entry. This was an inconvenience rather than a setback and work progressed on the unmanned full-size R-1, which was expected to ready for an orbital flight towards the end of 1964. If the test went according to plan, then the manned R-2 would be ready for launch into orbit during 1965. Subsequent flights would be used to test different systems and to validate reconnaissance and ASAT technologies, with missions eventually lasting for periods in excess of two weeks.

Although the R-1 and R-2 prototypes reached an advanced stage of construction, work was halted after Khrushchev was forced to step down from office. As a consequence his supporters, who included Chelomei, found themselves out in the cold. By January 1965 the Raketoplan had been formally cancelled. All research documentation for Raketoplan and previous spaceplane projects was collected and transported to the Mikoyan-Guryevich (MiG) OKB-155 and most of the scientists and engineers who had worked on these projects were re-assigned to MiG.

Spiral

Like many other Soviet military programmes, Project Spiral was highly classified and few details reached Western intelligence. Although the American X-20 spaceplane had been abandoned in 1963, the engineers at OKB-155 believed they could not only match the American design but significantly improve it. An entirely different launch system would be used. However, OKB-155 was not the only design and development organisation to undertake a new military spaceplane study. The Sukhoi Bureau had been approached by the Ministry of Defence to



This photograph shows a small model of the Hypersonic Launch Vehicle (HLV) designed for the Spiral programme. Development began at Tupolev during the mid-1960s, but the project was finally abandoned for technical and financial reasons. NASA

examine the possibility of developing a small spaceplane that would utilise a large high performance aircraft as the first stage in the system. Sukhoi was already working on an advanced but conventionally-powered Mach 3 aircraft called the T-4 and this would be used as a launch vehicle. The T-4 has been viewed as a Soviet attempt to reproduce the American XB-70A Valkyrie, but the 146ft (44.5m) long aircraft was probably closer to the proposed US XF-108 Rapier Mach 3 interceptor cancelled in 1959. Sukhoi's engineers were certainly aware of American proposals to utilise the XB-70A as a high performance launcher for the X-20 and its booster stage and their concept for a spaceplane system was broadly similar. However, the project never moved forward and may have been abandoned due to ongoing technical problems with the T-4. Although this aircraft eventually flew, it was not a success and finally met with cancellation in the early 1970s.

OKB-155 had been the favoured design bureau to build a military spaceplane for some time and initial studies for Project Spiral (also known as Article 50) began on 1st June 1965. Once these proposals had been completed, they were submitted to the Ministry of Defence who granted approval on 26th June 1966. This was swiftly followed by the appointment of Gleb Lozino-Lozinsky as the project's manager. Spiral would differ considerably from the earlier designs and now comprised three different integrated components. The first major part of the new system would be a fully re-usable, air-breathing hypersonic launch vehicle which was sub-contracted to Tupolev's OKB-156 Bureau for development and construction. This large arrowhead-shaped vehicle was to have an overall length of 124ft 8in (38m) and a wingspan of 54ft (16.5m), although figures quoted for the specification vary, perhaps reflecting design evolution.

Flown by a crew of two, the hypersonic launch vehicle (HLV) would be powered by a ventral pack containing four high performance Tumansky turbo-ramjet engines running on conventional aviation fuel. It was anticipated that this would provide a performance of Mach 4 at a maximum altitude of 78,000ft (24,000m). Tupolev hoped to upgrade the engines in due course to more advanced versions running on liquid hydrogen that would provide a Mach 6 capability at 100,000ft (30,500m). Carrying this type of fuel, the gross take-off weight was estimated to be approximately 114,600 lb (52,000kg). The spaceplane and its rocket booster would be transported in a semi-recessed fashion along the dorsal upper surface of the HLV's fuselage and lifted to high altitude for release. Tupolev believed the HLV had additional potential for use as a long-range reconnaissance/strike aircraft. It would have the ability to cruise at Mach 4 over a range of 3,700 to 4,400 miles (6,000 to 7,000km) and the hydrogen-fuelled version could make a brief hypersonic dash. Work on this section of the project is thought to have started in early 1967.

The second component of the Spiral design was an expendable rocket booster that would carry the spaceplane into orbit after release from the HLV. Various adaptations from existing upper stages were considered and the final choice was a booster burning liquid hydrogen and fluorine. The Spiral spaceplane was a flat-bottomed lifting body design and its rounded upturned nose soon earned it the unofficial name Lapot, which means wooden shoe in Russian. Much of this design was based on Myasishchev's heavily revised VKA-2, although scientists at OKB-155 found that the unusual upturned nose significantly reduced afterbody heating (this was later chosen by NASA Langley for its un-built HL-20 design). Another unique feature of the Spiral was the variable dihedral wings which could be adjusted after re-entry to significantly improve lift and control. The blended leading edge had a sharp 78° sweep and the short adjustable wings were set at 55°. There was a single tailfin and the spacecraft was equipped with control surfaces and brakes on the upper rear of the fuselage.

An upgradeable liquid fuel rocket engine would be used for orbital manoeuvring and de-orbit, along with two low-thrust supplementary engines for emergency use and a reaction control system. In addition to the initial launch flexibility which allowed a wide range of 93-mile (150km) high orbits, the spacecraft's rocket engine would permit adjustments to inclination as great as 17° in the reconnaissance and intercept roles or 7° for a surface strike mission. Cross-range performance appears to have been good, with estimates suggesting 932 miles (1,500km). It was also planned to install an RD-36-35K turbojet below the tailfin to improve landing control. Enough fuel was available for ten minutes of powered flight at full thrust which would be sufficient for an emergency fly-around at an airfield or a short diversion to an alternative site. Touchdown would be achieved using extendable skids, the forward legs of which were housed in the sides of the fuselage.

The cockpit was very similar to the earlier designs for spaceplanes and it was effectively an enclosed re-entry capsule capable of being ejected in an emergency from sea level to orbit. Preliminary estimates for the spaceplane's size suggest a length of 26ft (8.0m) and an overall span of 13ft (4.0m). Launch weight would be 19,400 lb (8,800kg) for all projected missions, with 1,102 lb (500kg) of this figure allocated to reconnaissance or combat payloads and 4,400 lb (2,000kg) for surface attack missions. The payload bay was located directly behind the cockpit and offered 21.5ft^3 (2m^3) of volume.

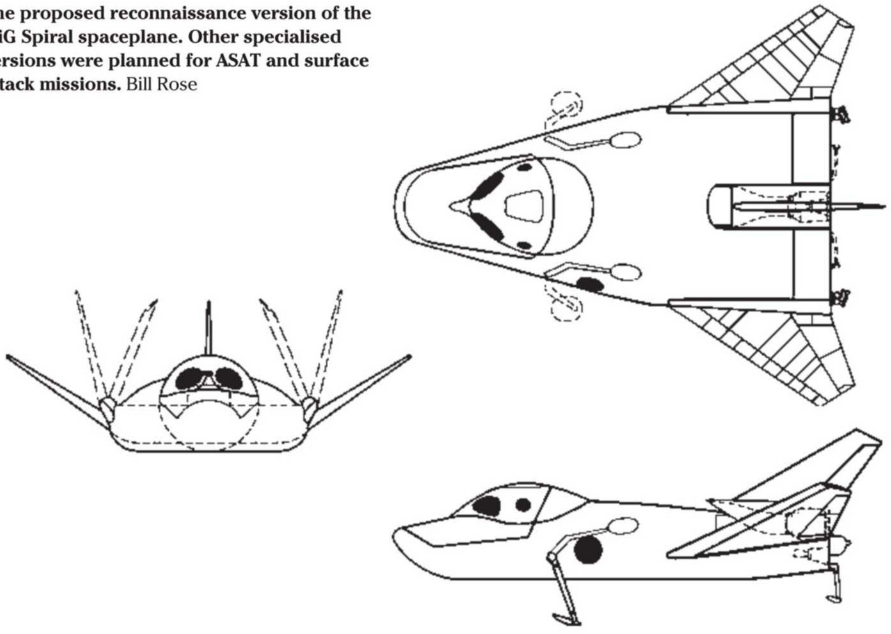
The primary use of this vehicle would have been pre-planned, short duration daylight photographic reconnaissance missions using an optical unit capable of obtaining photographic images with 4ft (1.2m) resolution from an 80-mile (130km) high orbit. Radar and ELINT sensors were a secondary consideration. As an offensive weapon system the

Spiral spaceplane would be able to undertake a missile attack on one or more surface locations. The highest priority target envisaged for the spaceplane was an American aircraft carrier cruising at a speed of up to 32 knots (59km/h). For this mission a single space-to-ground missile weighing 3,747 lb (1,700kg) would have been launched on approach from beyond the horizon, and it seems likely that a low yield nuclear warhead would be used.

Spiral was also designed to intercept, inspect and destroy manned or unmanned US spacecraft, and for this purpose it could be adapted to carry six 55 lb (25kg) space-to-space missiles developed by the Special Purpose Design Bureau (SKB). These weapons had an effective range of 18 miles (30km) and comprised a guidance and control system, an explosive warhead and a compact rocket motor.

With no aerodynamic requirements the missile's appearance was closer to a small satellite than an aircraft-launched weapon. It is not known if this technology was ever tested in space. As a long-range interceptor the Spiral would carry enough fuel to engage up to two targets in orbits as high as 620 miles (1,000km). It is possible that larger missiles with a greater range were intended for this role.

Once the specifications for Spiral had been formalised it was decided to build three prototypes, and it was hoped to begin subsonic tests by the end of 1967 using the first vehicle designated Article 105-11. This prototype would be air-launched from a Tupolev Tu-95KM and propelled by two liquid-fuel rocket engines. It would be followed in 1968 with supersonic trials of Article 105-12 and the first unmanned orbital flight of Article 105-13 would take place in 1970. At about the same time the first of four Tupolev HLVs would be ready for testing and, assuming things went according to plan, a manned Spiral flight would take place by 1972. This would be followed by a period of further development with the system becoming available for operational deployment around 1977.



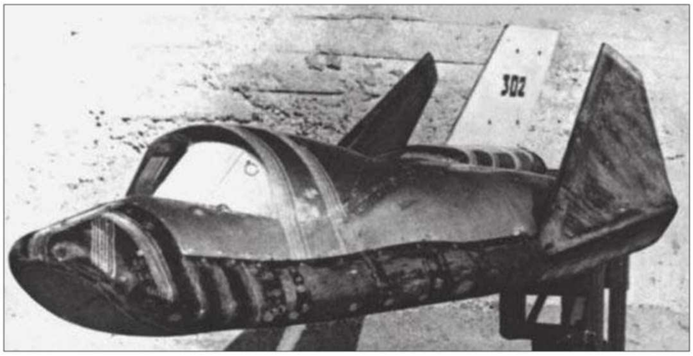
The proposed reconnaissance version of the MiG Spiral spaceplane. Other specialised versions were planned for ASAT and surface attack missions. Bill Rose

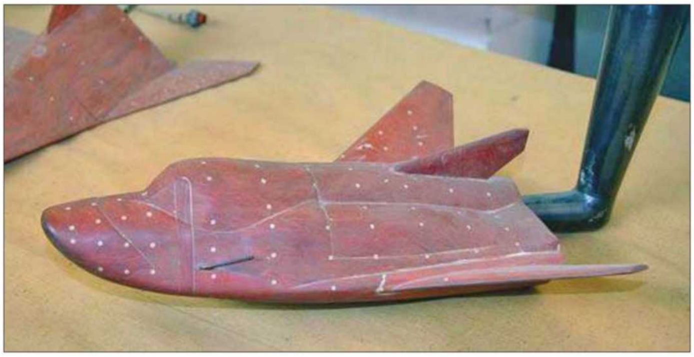
In 1967 a group of cosmonauts headed by Gherman Titov were selected to fly the Spiral. While wind tunnel testing continued at TsAGI to refine heat shield materials, it was decided to build several scale-sized, unmanned test vehicles known as Bezpilotniye Orbitainiye Raketoplan (unpiloted orbital rocketplane – BOR) for sub-orbital testing. Between 1968 and 1969 three BOR scale models were rocket launched from the Plesetsk test site near Archangel in the North and they travelled to Kapustin Yar near the Volga River Delta. The BOR-1 to BOR-3 tests were judged a success, but there was a serious lack of funding caused by the secret Soviet Moon Project and the Spiral programme slowed to a walking pace. A modest amount of research continued until 9th December 1970 when the bureau's chief Artyom Mikoyan died. He had been an enthusiastic advocate of Spiral and this was really bad news. Furthermore, Gherman Titov had left the programme and the Tupolev OKB was experiencing major technical problems with the HLV. Within a matter of weeks after Mikoyan's death the Spiral project was formally reviewed on the authority of Soviet Defence Minister Andrei Grechko (1903-1976) and immediately cancelled.

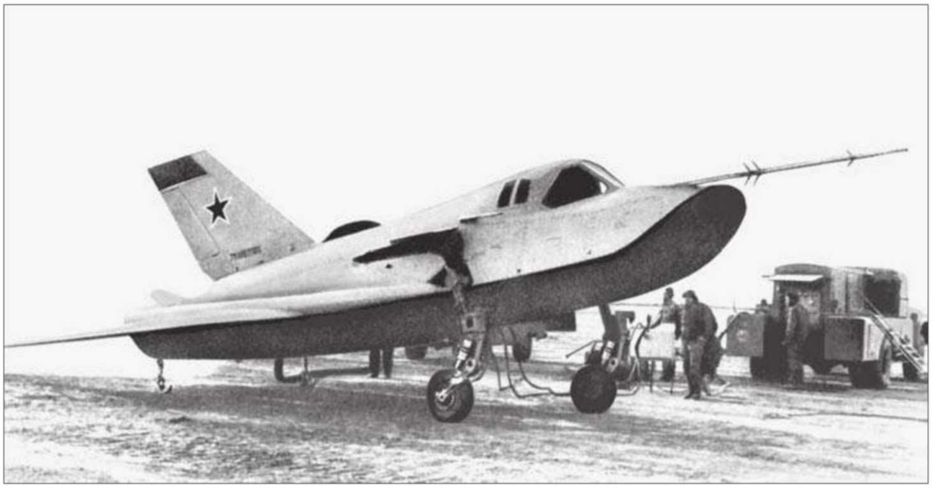
That might have been the end of the story, but America was pressing ahead with its Space Shuttle programme which the Soviet military regarded as a serious threat. As a consequence the Spiral programme was unexpectedly revived under pressure from rocket engine designer Valentin Glushko (1908-1989), who now held the same status within the Soviet system as his former colleague Korolev. Nevertheless, by the start of 1972 the Spiral project was in tatters. There was no

Below left: **The BOR-3 experimental lifting body vehicle which undertook a sub-orbital test flight in the late 1960s as part of the MiG Spiral spaceplane project.** RKK Energia

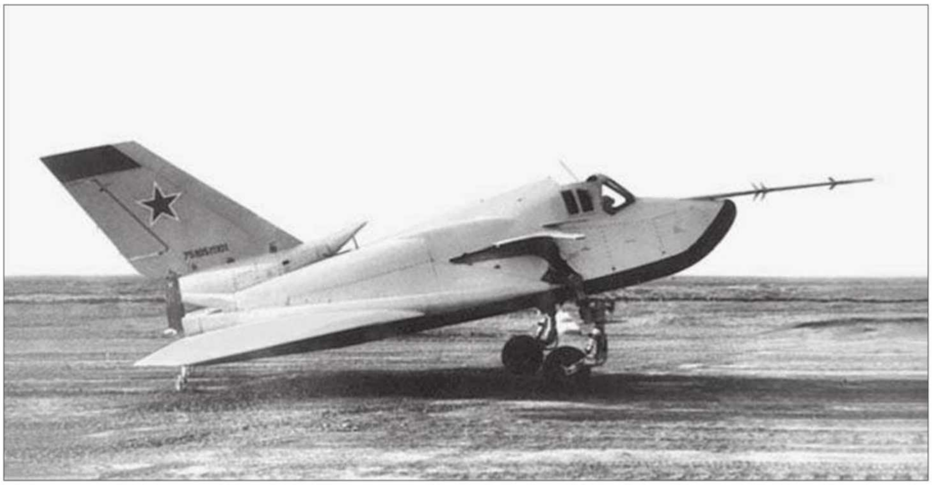
Below right: **A small wooden model of the BOR-4 vehicle produced at TsAGI during the 1970s. In the background is what appears to be a wooden model of the earlier M.48 spaceplane.** RKK Energia







Atmospheric test version of the MiG spaceplane designated 105-11. This prototype was equipped with many components intended for use with the more advanced versions. NPO Mash



The MiG-105.11 spaceplane following a test flight. The short wings appear to be fixed. NPO Mash

Tupolev HLV, no booster stage, important members of staff had been moved to other duties and all that remained were the three mothballed prototypes and several rooms filled with research documentation.

Although the scale of the revived programme would be fairly low key, it was decided that test flights would commence using the Article 105.11 prototype. Russia would eventually have to match the US Shuttle and the MiG spaceplane would be a useful step in the right direction. Little seems to have happened during the next three years with the focus of attention shifting elsewhere, but Article 105.11 underwent a number of modifications that included the replacement of the escape capsule with a standard ejection seat and a revision of the controls and instruments. Article 105.11 was also given a new name, Experimental Passenger Orbital Aircraft or EPOS, although it is unclear who this slightly deceptive title was aimed at because the project remained highly classified. Ground tests of the MiG-105.11 began in late 1975 and by mid-1976 had progressed to taxying trials and brief runway lift-offs under jet engine power.

On 11th October 1976 MiG-105.11 allegedly made a very short jet-powered flight from a small airfield to the Ramenskoye (later Zhukovsky) Test Centre some 11 miles (19km) distant. This was followed in 1977 by a several captive test flights and a series of piloted air-drops using a Tupolev Tu-95K. One unusual incident arose at the start of the runway test-flights when the craft's skids began sinking into the tarmac because of exceptional summer heat. A quick solution was found to reduce friction and several truckloads of watermelons were obtained from a nearby farm, broken up and spread along a 230ft (70m) stretch of runway. This solved the immediate problem, but soon afterwards wheels and tyres were attached to the forward skids. The final flight in the series was made on 1st September 1978 but ended badly when the MiG made an especially hard landing on the runway at the Air Force's Akhtubinsk R&D Institute, which resulting in serious damage to the airframe. According to some reports repairs were carried out, but a decision was made to cancel the project and Article 105.11 never flew again. The prototype is now on display at the Monino Air Force Museum near Moscow.

The supersonic 105.12 prototype was also brought up to flight readiness status but never flew. Its whereabouts are unknown, but it may still exist. The hypersonic 105.13 was used for static testing and its fate is also unknown. Once the Spiral programme had been shut down Project Manager Gleb Lozino-Lozinsky was put in charge of developing the Buran airframe (below).

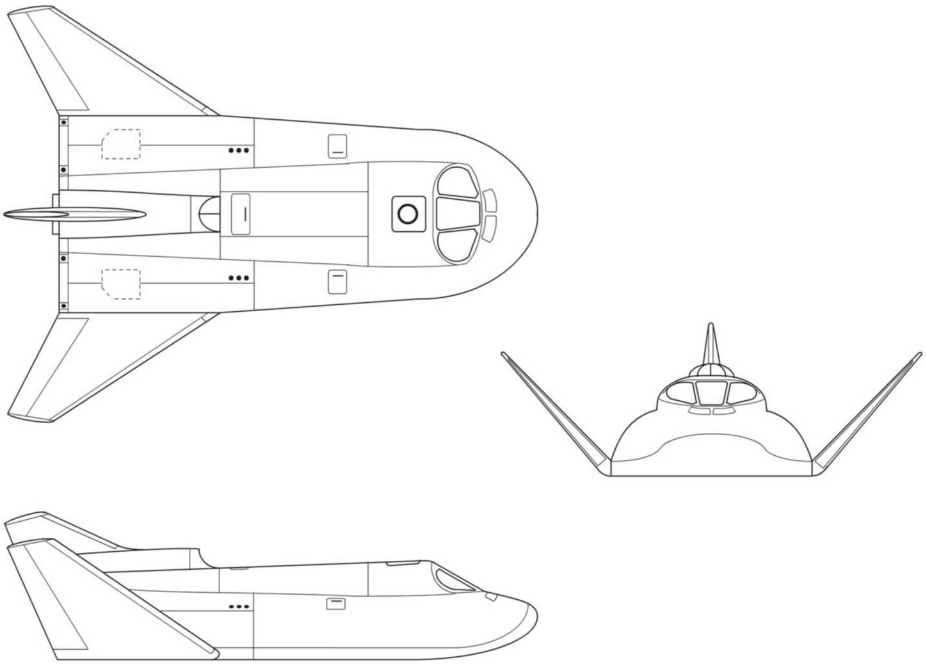
Uragan

Although Spiral continued into the 1970s as a low-level research project, it led to a slightly larger manned military spacecraft that remains classified and was developed specifically to destroy US Space Shuttles. Launched with a Zenit rocket, this spacecraft was allegedly called Uragan (Hurricane) and some observers believe that the project reached an advanced stage of development.

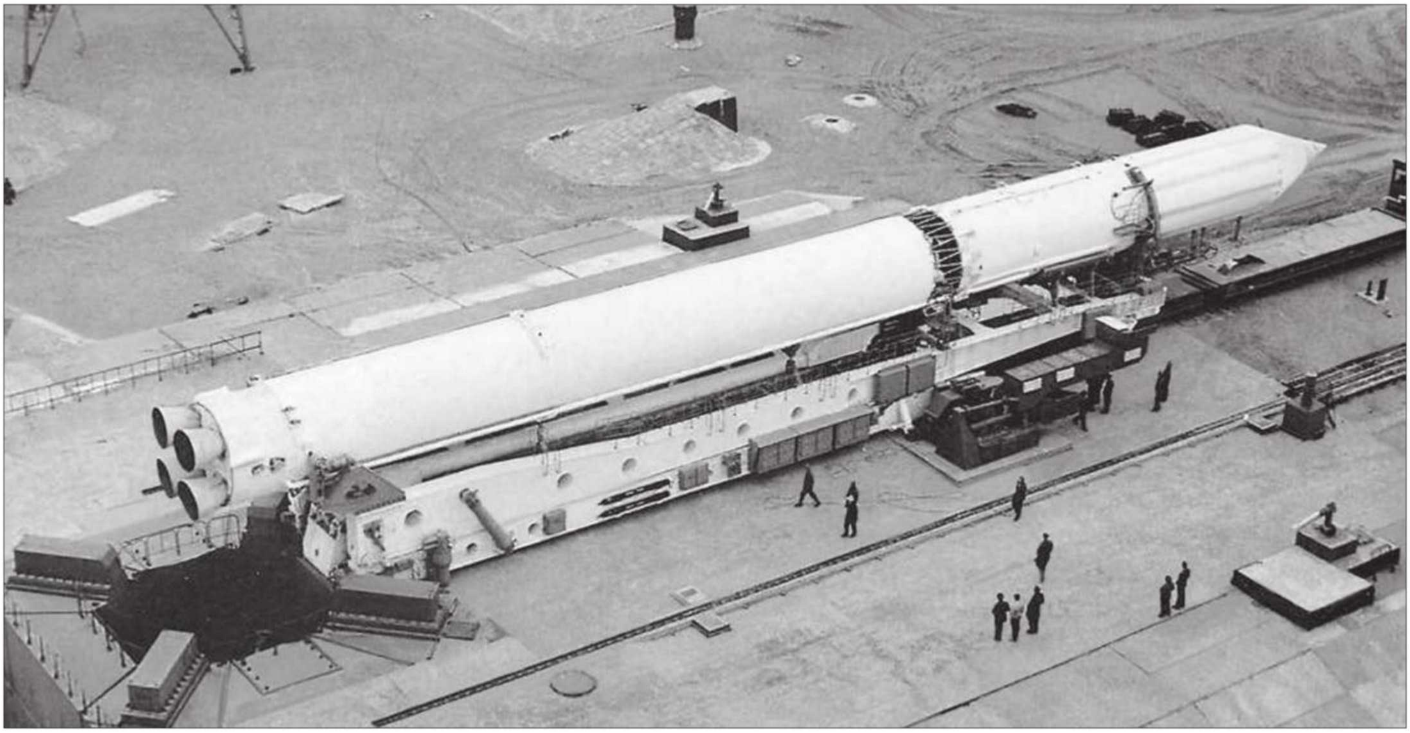
On 14th April 1972 NASA announced that most of its Shuttle flights would be undertaken from the Kennedy Space Center. In addition the USAF had selected Vandenberg for military polar missions. In fact there was little choice for a secondary site on the North American Continent and the only other option had been WSMR, which finally met with rejection for safety reasons. As development of the US Shuttle picked up momentum during the 1970s, the Soviet leadership became increasingly concerned that much of Russia would be vulnerable to pre-emptive nuclear attacks from this new type of space vehicle. What followed remains a matter of speculation, but it seems likely that when tests of the MiG-105.11 began plans were already being drawn up for a more advanced version of the small spaceplane. Launched by a Ukrainian-manufactured Zenit expendable booster this vehicle could be put into service reasonably quickly, although using a rocket would remove the flexibility originally envisaged for Spiral.

Directly based on the Spiral spaceplane and developed by MiG, some reports describe the Uragan as being a two-man lifting-body design with a length of 41ft (12.5m), a span of 31ft (9.5m) and a launch mass of 28,660lb (13,000kg). Many earlier features of Spiral such as the adjustable wings were retained and Uragan might be regarded as a significant upgrade. Its primary role would be the interception of US Shuttles, and the most probable weapon would be an SKB-developed space-to-space missile. It is also likely that Uragan could have undertaken reconnaissance, ASAT and space station defence missions. By the mid-1970s work had started on the Buran shuttle project and there have been suggestions that Uragan never actually existed and was simply part of a disinformation campaign. However, a series of BOR-4 scale-model test flights undertaken during the early 1980s suggests that a small Soviet spaceplane was still in development.

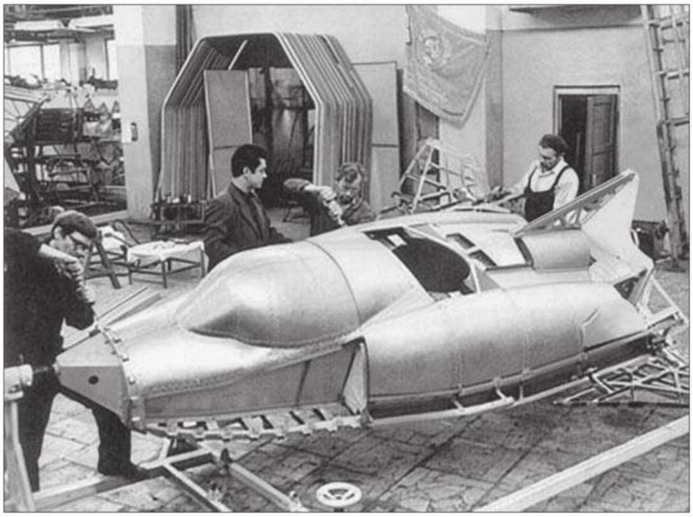
The first BOR-4 launch took place at Kapustin Yar in early December 1980 but no details have been released. This was followed by a second test flight designated Kosmos-1374 on 3rd June 1982. The BOR-4 test vehicle landed in the Indian Ocean but its position was approximately 125 miles (200km) from the recovery group. As the Soviet ships reached BOR-4, a Lockheed P-3C Orion belonging to the Royal Australian Air Force also arrived on the scene and photographed the recovery in great detail. A third test flight designated Kosmos-1445 was made on 15th March 1983 with a recovery in the Indian Ocean during the following day. Once again an RAAF P-3C Orion was in the area to make a number of fairly daring low-level passes of the operation to secure high quality photographs. This clearly angered the Russians and the next BOR-4 launch (Kosmos-1517) at the end of 1983 landed in the Black Sea. Two further launches took place in 1984, with the second flight designated Kosmos-1614 performing faultlessly until it splashed down in the Black Sea and sank without trace. In total three BOR-4 test articles were manufactured and it is thought that the final BOR-4 test flight was successfully undertaken from Kapustin Yar on 20th October 1987.

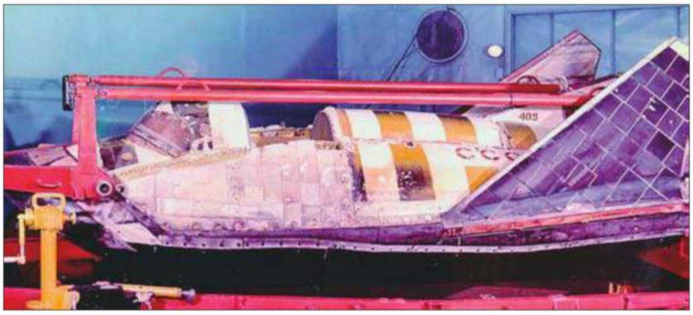


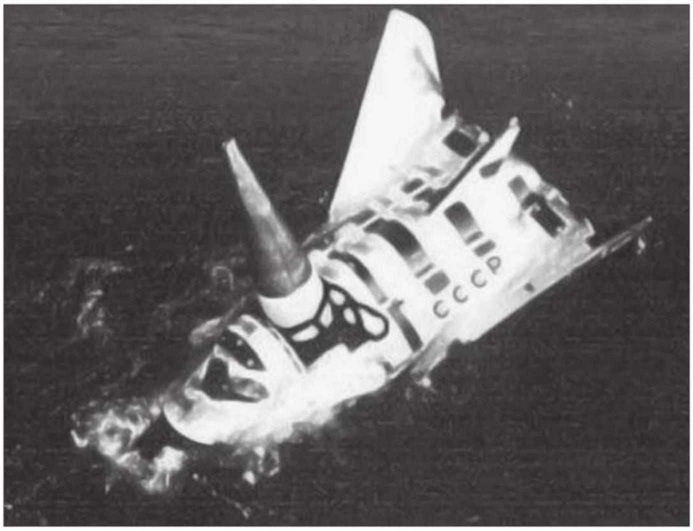
Officially the MiG Uragan (Hurricane) spaceplane project never existed, but there are detailed reports that suggest that this small military spaceplane was developed. Chris Gibson

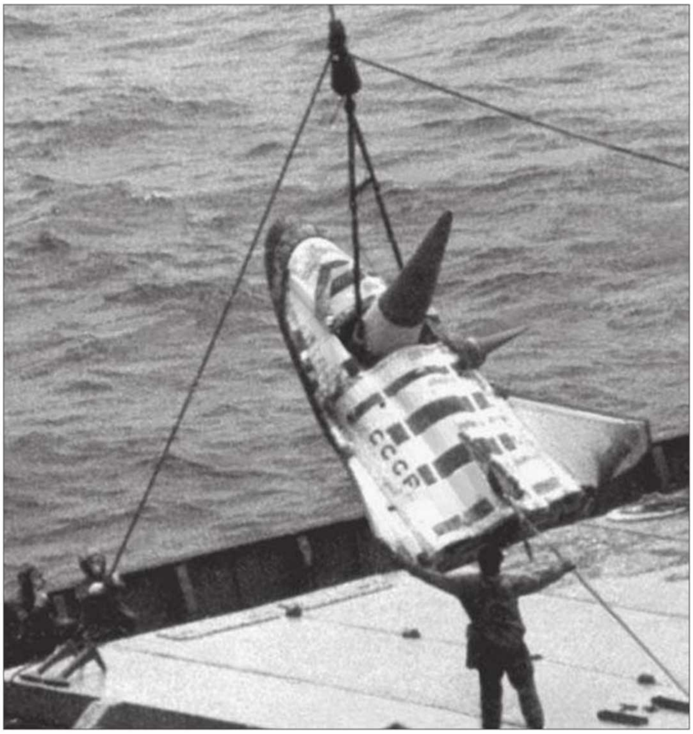


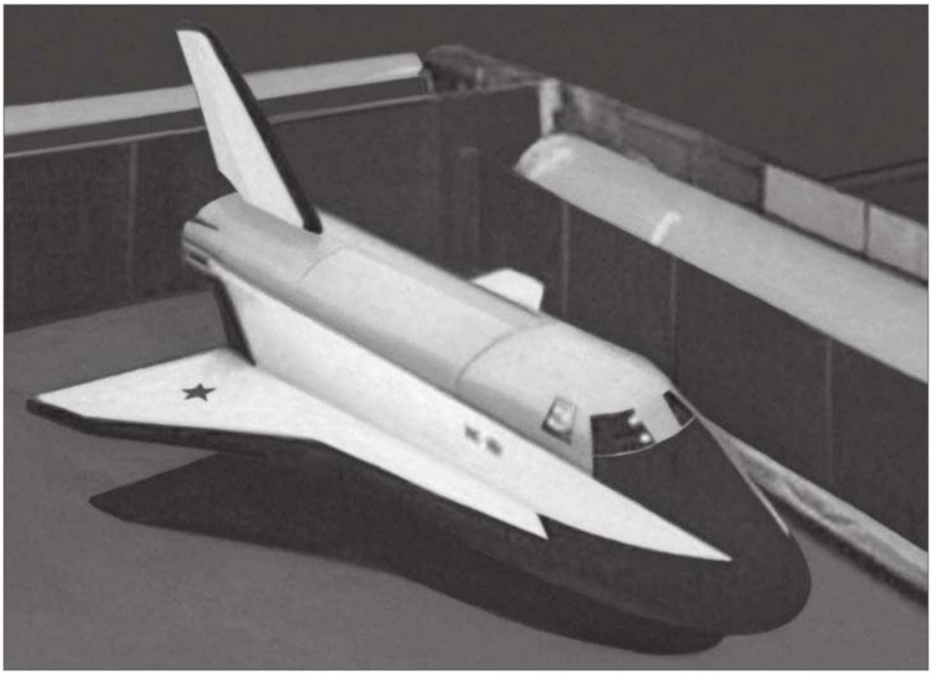
The advanced Zenit rocket was developed in the 1970s as a liquid-fuelled booster for the Energia rocket and as a Soyuz replacement. It has also been suggested that this rocket would have been used as the launcher for the Uragan military spaceplane. RKK Energia











Top left: **A staged photograph showing the assembly of a BOR-4 flight test vehicle at the factory.** RKK Energia

Top right: **A BOR-4 test vehicle in a transportation cradle. Five test launches were made but the exact number of BOR-4 vehicles built remains uncertain.**

Above left and right: **A BOR 4 test vehicle launched under the cover of Cosmos 1445 seen after splash down in the Indian Ocean in March 1983. The Soviet recovery operation was photographed in considerable detail by a circling Australian reconnaissance aircraft.** Royal Australian Air Force

Left: **This is one of the few existing photographs of the Chelomei-designed Light Space Plane (LKS), which was completed in 1980 as a mock-up in military markings. About half the length of Buran, it was intended for use with a number of different launch systems and would fly manned or unmanned. Resembling a cross between the Buran and the more advanced MAKS, the LKS was also configured with twin tailfins.** NPO Mash

The status of the Uragan project at this point in time is unknown, but the destruction of America's Challenger Shuttle on 28th January 1986 had serious consequences for American manned spaceflight and virtually meant the end of USAF involvement with this system. It led to the abandonment of the largely completed launch complex at Vandenberg AFB and by 1988 the threat of a surprise attack on Russia from a Shuttle in polar orbit had been removed. Whether or not MiG built any prototype Uragan spaceplanes remains unknown and the Russian authorities continue to deny this project's existence. But according to Richard Ward who worked for Lockheed as a technology analyst, he was told about Uragan during high-level discussions with Russian engineers in May 1990.

LKS

When Professor Chelomei lost favour with the politicians in 1964 his Raketoplan project was cancelled immediately, although he managed to retain control of OKB-52 which by all accounts was one of the best-run aerospace organisations in Russia. In the years that followed Chelomei continued to privately develop a re-usable spaceplane which utilised the best features of several earlier designs. The vehicle made extensive use of readily available components developed for the Almaz space station and bore quite a resemblance to the later MAKS spaceplane.

Chelomei called his design the Light Space Plane (LKS) and plans for a prototype were completed by 1980. Chelomei had attempted to participate in the Buran project but couldn't agree with the push towards duplication of the US Shuttle and finally withdrew. He believed that a lower cost vehicle which was half the size of America's spaceplane was the answer and a design like LKS could utilise a number of different launch systems that included the Proton rocket, sleds on rails, large aircraft and even a version of the Soviet Ekranoplan. The LKS had an approximate length of 62ft (19m), a span of 36ft (11m) and a mass of 55,000 lb (25,000kg). The payload capability would be 9,900 lb (4,500kg) and it would be equipped with a single liquid-fuel rocket engine for orbital manoeuvring and de-orbit that was capable of providing a delta v of 820ft/sec (250m/s). Additionally, there would be a reaction control system.

Flown by a crew of two or three, the vehicle would have an endurance of ten days but could remain in orbit unmanned for up to one year. Thermal management remains somewhat unclear, but it was planned to do away with tiles and use a continuous heat shield layer developed for the TKS spacecraft, which was expected to remain usable for at least one hundred missions. The cross-range was good and after re-entry the LKS would glide to a landing site, touching down with a conventional nosewheel and two extendible skids. LKS would use a single or twin tailfin arrangement, a double delta wing and a centrally-located payload bay. An idea borrowed from the US Shuttle was a robotic arm and the spacecraft was primarily intended for military use, but could be configured to transport personnel and cargo to an orbital space station.

As a military spacecraft Chelomei envisaged the LKS carrying a high-powered laser weapon in the cargo bay that had the ability to destroy American ICBMs. He used this concept to secure high-level military support but the proposal was rather unrealistic for that time. Nonetheless, Chelomei was determined to secure official support and he appointed B N Natarov as project manager, who would answer directly to Chelomei's deputy Herbert Efremov. Extensive proposals were drawn up for the construction of a fleet of Proton-launched vehicles able to undertake up to ninety flights per year. During 1980 a full size mock-up of LKS was completed at OKB-52 in the astonishingly short space of about one month. This was made possible by salvaging many of the parts from earlier spaceplane programmes. The LKS model was painted in Air Force colours and Chelomei invited a high-level military delegation to visit the facility and inspect it. Chelomei hoped this move would be sufficient to have the Buran project cancelled and his design accepted in its place. He was promising an operational spacecraft within four years and very substantial cost savings, which clearly impressed the visitors.

Unfortunately for Chelomei he still had powerful enemies within the establishment and further development of the LKS was halted in 1983 pending a full review. This was held in September of that year and chaired by A P Aleksandrov from the Academy of Sciences. Chelomei and his deputy Efremov put their case to the committee, but it appears to have been a waste of time. The review concluded by rejecting the LKS and reprimanding Chelomei for spending money on a project that had not received official approval. NPO Energiya, controlled by Valentin Glushko, had been contracted to build the ultimately ill-fated Buran space system and there would be no turning back from this multi-billion rouble project. It was the end of Chelomei's dream to build a small spaceplane and he decided to retire. The following year Chelomei was injured in a minor car accident that led to complications and he died of an arterial blockage on 8th December 1984. Curiously, an unknown number of intruders broke into the factory (which was now known as NPO Mashinostroyeniye) on 1st March 1991 and destroyed the LKS mock-up. Rumours persist that members of the KGB took this action having been ordered to ensure that the project was never revived. Bearing in mind that NPO Mashinostroyeniye was (and still is) a major centre for the development of Russia's strategic nuclear arsenal, the likelihood of vandals or criminals gaining easy access to this facility would seem improbable.

MAKS

Work on the Mnogotselevaya Aviatsiniya Kosmicheskiye Sistema (Multipurpose Aerospace System), better known as MAKS, started before the first Buran flight. This scaled-down version of the Buran emerged from a series of officially sponsored studies in the early 1980s called Project OK-M. The study attempted to determine the validity of a spaceplane replacement for the Soyuz and Progress spacecraft. The military considerations are unknown, but this small spaceplane would have been capable of undertaking a range of different missions from reconnaissance to anti-satellite operations. One part of the OK-M programme concentrated on a Zenit booster-launched design and was undertaken by NPO Energia, while the other proposal was for an aircraft-launched system similar in some respects to the USAF's Sortie vehicle concept which is described in Chapter Three.

The air-launched proposal was undertaken by OKB Molniya and evolved into a more sophisticated system known as MAKS, which would comprise the spaceplane, a large jettisonable fuel tank and a modified Antonov An-225 carrier aircraft. The MAKS spaceplane was to be flown by a crew of two and release from the carrier aircraft would take place at an altitude of 28,000ft (8,600m) and at a speed of approximately 559mph (900km/h). After release it would then climb under its own power for a rocket burn time of 440 seconds. When the fuel was exhausted the 105ft (32m) long external fuel tank would be jettisoned. MAKS was expected to deliver an 8.3 ton (7.5 tonne) payload to a 124-mile (200km) orbit with a 51° inclination. The spacecraft would have an overall length of 63ft 4in (19.3m), a wingspan of 41ft (12.5m) and a payload bay measuring 22ft 3in (6.8m) long with a width of 9ft 2in (2.8m). MAKS would use two advanced Glushko RD-701 tri-propellant engines, initially using liquid oxygen and kerosene but then switching at higher altitude to liquid oxygen and hydrogen which would provide less thrust but a higher specific impulse. The engine was built and successfully tested on a number of occasions with each unit having an estimated life expectancy of fifteen MAKS missions. Re-entry heat shielding was similar to Buran and on the completion of a mission MAKS would make a horizontal runway landing after deploying its conventional undercarriage.

Two further versions of MAKS were proposed. The first was the unmanned MAKS-T intended to place larger 18 ton (16.3 tonne) payloads into LEO. The second was a more sophisticated fully-reusable manned vehicle called MAKS-M which would not require an external fuel tank. However, the MAKS spaceplane was cancelled in 1991 due to national economic difficulties. Much of the MAKS hardware was completed and a mock-up of the spaceplane had been built but, despite NPO Molniya's best efforts to promote the system's civil potential, MAKS failed to attract any financial support.

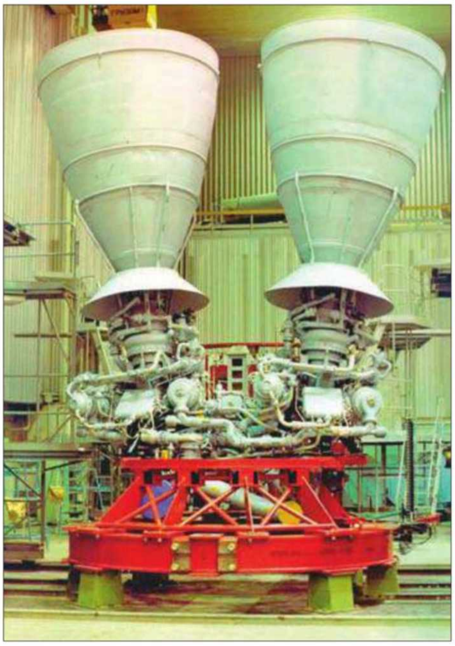
Buran

From the very outset Soviet politicians were convinced that the US Space Shuttle was being developed to attack Russia. This fear was talked up by Mstislav Keldysh who convinced the leadership that the Shuttle's manoeuvrability would allow it to outflank existing anti-missile defences and launch a nuclear strike against Moscow. One major factor throughout the Cold War was the entrenched belief on either side that enemy capabilities had to be matched to maintain the balance of power, so concerns within the Kremlin about the forthcoming US Shuttle would lead to the most costly and pointless expenditure on space hardware in Russian history. The choice of a development bureau for the Soviet Shuttle was largely decided before any formal request had been issued. The new Soviet spacecraft would be handled by OKB-1 (which became NPO Energia) in Kaliningrad. This was run by Valentin Glushko who had been personally appointed to this position by Chairman Brezhnev in 1974. On 12th February 1976 NPO Energiya was authorised to proceed with the re-usable spaceplane under direction from the Ministry of Defence and the project was assigned the name Buran. TsAGI was already undertaking R&D for the new project and MiG was appointed as the main sub-contractor, which led to the formation of a new design bureau called Molniya run by former chief designer Gleb Lozino-Lozinsky.

It seems obvious that the US Shuttle was used as the starting point for Buran and there would have been little point in attempting to build such a costly re-usable system on the basis of beginning with a blank sheet of paper. However, Buran was not a slavish copy of the Shuttle and evolved into a different system in the same way that the Sukhoi Su-27 fighter differed from the American F-15, despite some superficial similarities. Buran had a length of 120ft (36.5m) a span of 78ft 6in (24m), a 60ft 10in (18.55m) long cargo bay and the maximum payload has been quoted as approximately 66,138 lb (30,000kg). The vehicle utilised a conventional tricycle undercarriage and Russian engineers claimed that the heat shielding developed for Buran was superior to the American Shuttle. Buran was also designed from the outset to be usable as an unmanned spacecraft with a fully automated landing capability. One significant difference from the American system was the way Buran reached orbit – the spacecraft was simply a payload for the powerful Energia launcher. This is the opposite of the Shuttle which draws fuel from a large expendable tank for the spacecraft's engines and uses solid fuel boosters to assist the launch.

With initial research complete, the Buran received official approval during November 1977 and a development plan was laid down. To begin there would be a series of tests involving scale-sized BOR vehicles, and then a full-sized jet-powered demonstrator would be test flown. This would be followed by the first unmanned mission in 1984 and manned flights would begin in 1987. Ten operational Burans were planned and these would become the Soviet Union's principal manned space system. Buran was primarily intended for military operations which would be similar in nature to those suggested for the earlier spaceplanes. But the significantly larger payload capacity seems to have encouraged the idea of using the vehicle as an orbital platform to deliver nuclear space-to-ground missiles, which might have rivalled a missile-carrying nuclear submarine in terms of destructive capability. There was also growing Soviet interest in lasers and the idea of carrying a powerful directed-energy weapon in the cargo bay was considered. However, returning to my earlier comments concerning lasers, this technology lacked maturity and, just like similar US proposals, effective directed-energy weapons were still a long way from realisation.

As construction work began on a full-sized Buran prototype, the first test of a scale-sized BOR-5 model was undertaken at Kapustin Yar on 4th July 1983. In all six rocket-launched sub-orbital BOR-5 flights were made with the last taking place on 21st June 1988. These tests were instrumental in validating the initial aerodynamic research for Buran and none of the 3,090 lb (1,400kg) BOR-5 models was flown more than once, although four of the six vehicles were recovered. The jet engine-powered Buran (OK-GL-1) Analogue began taxying trials at Zhukovsky during December 1984 and the first test flight was made on the 10th October 1985 with Cosmonaut Igor Volk at the controls. When the Buran Analogue was first observed at Zhukovsky Airfield by American spy satellites it received the codename Ram-R, which was derived from the test site's original name – Ramenskoye. A total of 140 flights would be



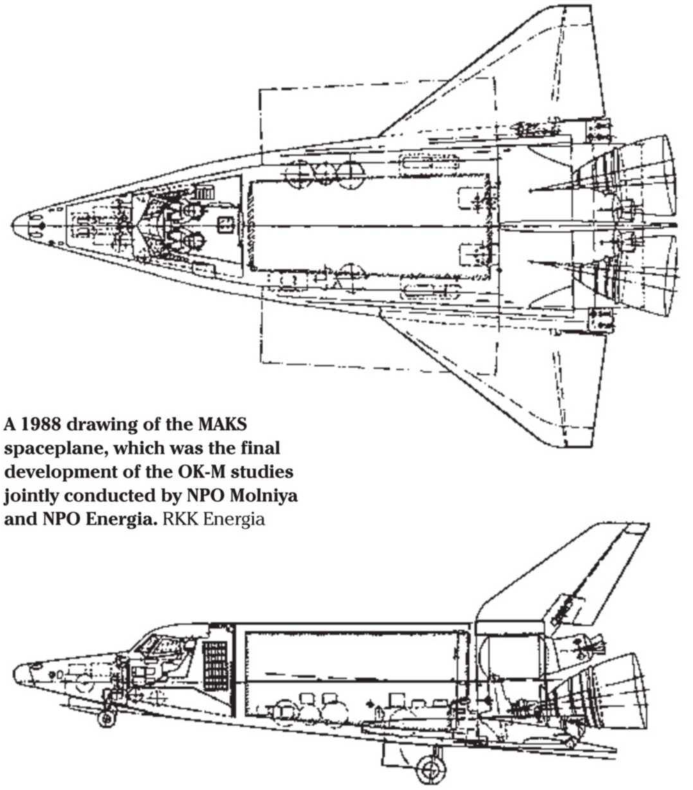
This page, left: **The RD-701 tri-propellant engine was specifically developed by Glushko for the MAKS spaceplane. This very efficient engine would initially use kerosene and LOX and then switch to liquid hydrogen and LOX to provide a higher specific impulse.** RKK Energia

Opposite page, far right, top to bottom:
Full-sized mock-up of the MAKS spaceplane which was expected to replace Soyuz. The project had been granted official approval to proceed but was suddenly cancelled when the Soviet Union collapsed. RKK Energia

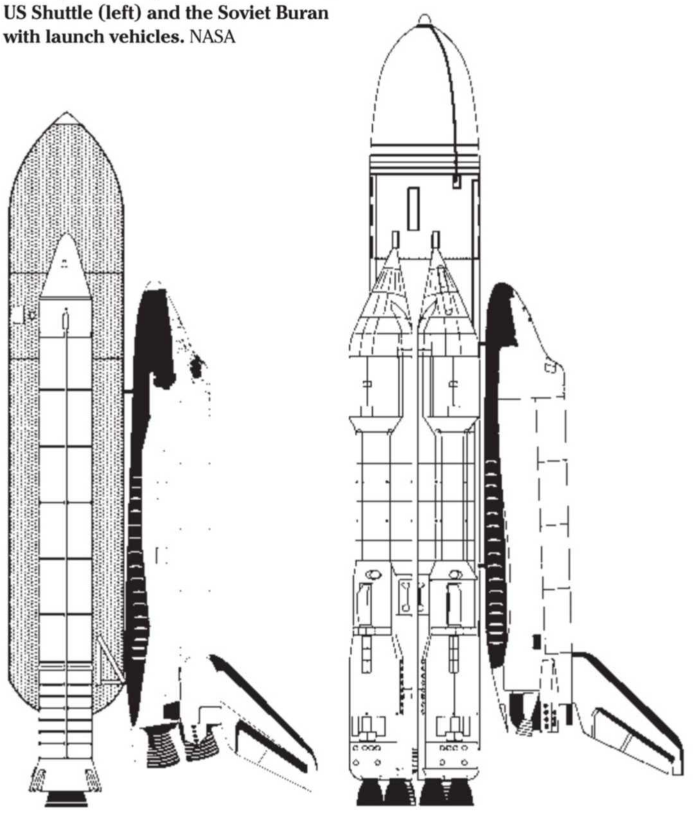
Engineering mock-up of the engine assembly for MAKS. RKK Energia

BOR 5 test vehicle, used in the development of the Buran Shuttle, is seen in its transportation cradle. Six test flights were made and four of the vehicles were recovered. None of the BOR-5s were used more than once and the final sub-orbital mission took place on 21st June 1988. RKK Energia

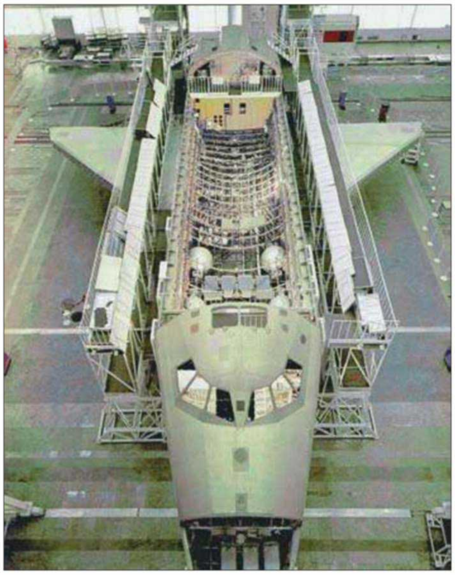
'Analogue' jet-powered version of the Buran (OK-GL-1) making a controlled landing. RKK Energia

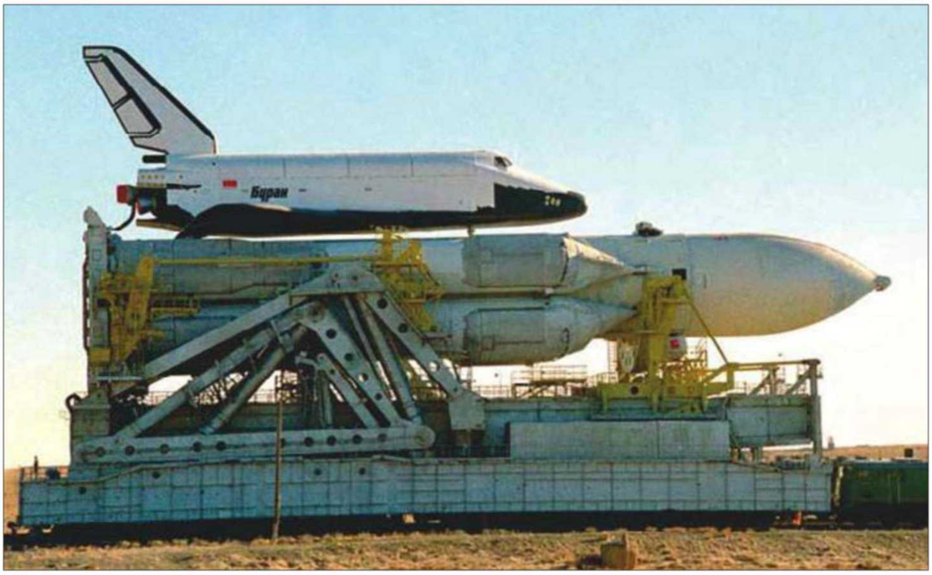


A 1988 drawing of the MAKS spaceplane, which was the final development of the OK-M studies jointly conducted by NPO Molniya and NPO Energia. RKK Energia



Side-by-side comparison between the US Shuttle (left) and the Soviet Buran with launch vehicles. NASA





Top left: **One of the Buran spacecraft undergoing assembly.** RKK Energia

Top right: **Buran and the Energia launch vehicle are moved on a massive transporter to the launch pad.** RKK Energia

Left: **The Buran space shuttle prior to lift-off.** RKK Energia

Opposite page: **Escorted by a MiG-25 chase plane, the unmanned Buran 1.01 touches down the Jubilee Runway at Baikonur after completing a 206-minute space flight.** RKK Energia

made with this AL-31 turbojet-powered Buran including sixty-nine fully automated runway landings at Zhukovsky and Baikonur. The Buran would take off normally under the power of its four turbojets, circle the airfield and then cut the engines to make a glide landing onto the runway.

Although static tests of Energia began in August 1986 and a successful launch took place during the following year, the Buran project was now three years behind schedule and generating increasing concern at the highest levels. Despite this slippage, flights were being planned and, following two or three unmanned missions, the first crewed Buran was to be launched in 1992 with Igor Volk and Aleksandr Ivanchenko at the controls. This would be followed by a rendezvous with the Mir space station and a series of longer duration orbital flights.

Development of the spacecraft proceeded with some difficulty until 15th November 1988 when the unmanned Buran 1.01 was launched into orbit from the Baikonur Cosmodrome using an Energia booster. Aside from having no life-support system or working cabin instrumentation, the spaceplane was fully functional and it attained an orbit with an apogee of 159 miles (256km) and an inclination of 51.6°. A retrofire de-orbit manoeuvre was made after 140 minutes and, having successfully completed two orbits, Buran 1.01 returned to make a fully automated touchdown on the Jubilee runway at the Baikonur Cosmodrome. The whole flight had lasted 206 minutes.

Western observers were convinced that manned missions would swiftly follow, but there were more delays and the schedule continued to slip until finally grinding to a complete halt when the Soviet economy collapsed. Although the construction of further vehicles continued, flight-testing was halted after the first unmanned mission due to funding problems and the worsening political crisis within the Soviet Union. This uncertainly continued until 30th June 1993 when President Boris Yeltsin formally pulled the plug on the Buran programme.

Buran 1.01 actually flew one more time attached to an Antonov An-225 transporter at the 1989 Paris Air Show, but this was the spacecraft's last outing and it stayed in a hangar at Baikonur until 2002 when the roof collapsed and the spacecraft was destroyed. Construction of Buran 1.02 (known as Ptichka – Little Bird) began in 1988 and it was planned to use this vehicle for the first manned mission. 1.02 was almost completed when the Buran programme met with cancellation and it remains mothballed in a hangar at the Baikonur Cosmodrome, now apparently belonging to the Kazakhstan Government after some unusual deal was struck with the Russians. Buran 2.01 (Baikal) was the third slightly upgraded vehicle commissioned in 1990 and it had reached a fairly advanced state of construction when the project ended. Eventually it was sold to an aviation museum in Sinsheim in Germany. Various other pieces of Buran hardware still exist and some are on public display in Russia and Europe, with perhaps the best know example being the OK-TVA static test Buran vehicle which is now a tourist attraction in Gorky Park. Mercifully, plans to convert it into a fast food restaurant never materialised and the spacecraft has recently undergone extensive restoration. But whichever way you look at it, the Buran programme was a total disaster that cost the country an estimated 20 billion roubles at a time of considerable financial difficulty.

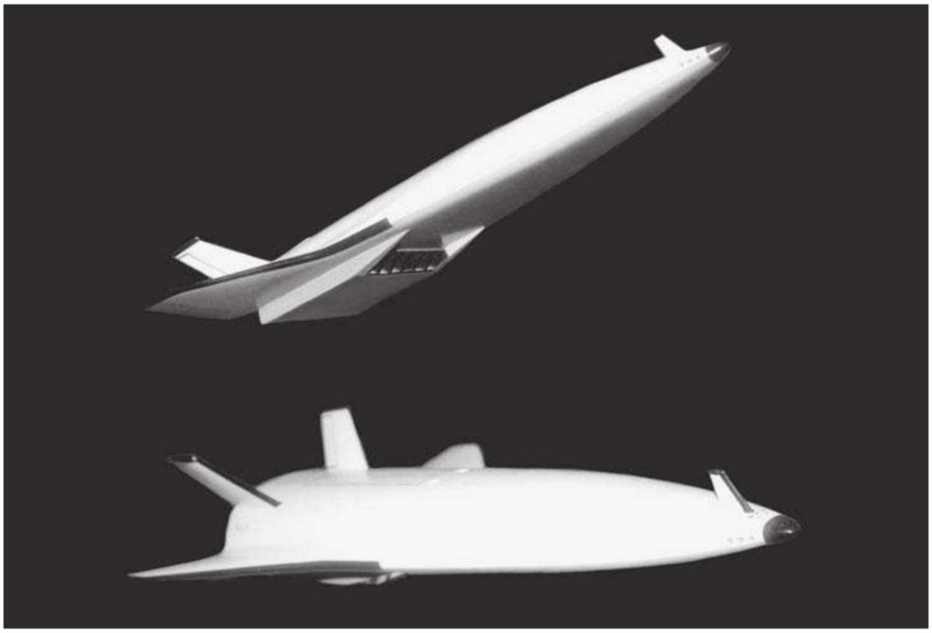
Russia's Aurora

A key factor throughout the Cold War was matching the opposition's technology, or at least giving the impression of doing so. A major Soviet concern was the NASP project and in response the Soviet Ministry of Defence issued a series of classified requests on 19th July 1986 for a fully re-usable SSTO spaceplane with a similar capability that would be available by 2000. Within months NPO Energia, Tupolev and Yakovlev had submitted basic outlines for a suitable vehicle. Various launch methods were considered, including a vertical system similar to the later Lockheed-Martin X-33 and a development of the original rail and sled concept proposed by Eugen Sänger. But the preferred choice was a vehicle that could utilise a conventional runway. The Soviet SSTO spaceplane was required to deliver a 25 ton (22.7 tonne) payload to a 125-mile (200km) orbit with a 51° inclination. Although the military uses of this vehicle remain vague, they probably mirrored intentions for the American NASP. The first Tupolev submission certainly looked similar to the initial NASP design in size, weight and capability. Little is known about the Yakovlev spacecraft, although it is thought to have been broadly similar to the Tupolev proposal.

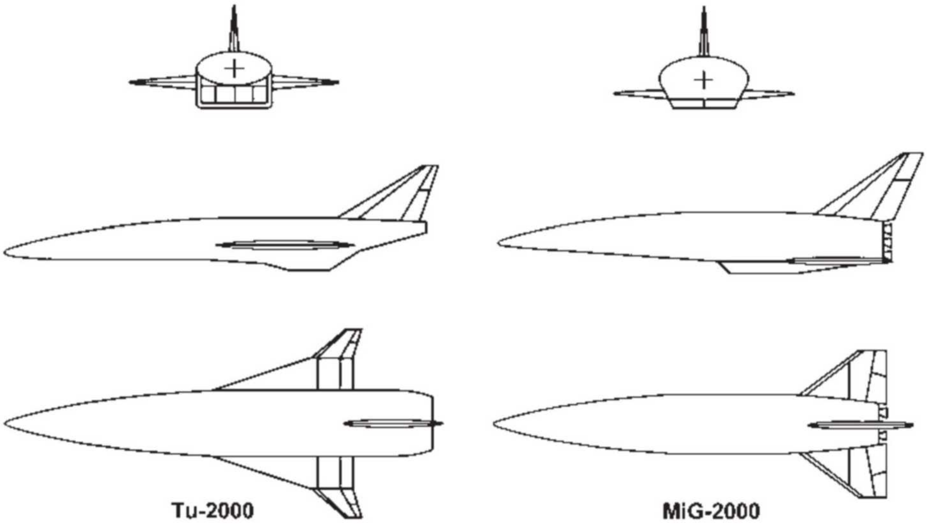
The third concept from NPO Energia was produced by the high-profile aircraft engineer Pavel Tsybin and this SSTO spaceplane would use a mixture of turbo-ramjet and rocket propulsion. Tsybin's vehicle had a length of 232ft (71m), a wingspan of 137ft (42m) and height 33ft (10m). The take-off mass would be 700 tons (635 tonnes), most of which comprised liquid hydrogen fuel. A late submission was received from MiG which used a launch sled, but this was rejected in early 1988 when the Soviet Ministry of Defence selected the Tupolev proposal for further development as Russia's new SSTO spaceplane.

An initial proof-of-concept hypersonic vehicle was to be built and the designation Tu-2000A was assigned to the prototype. The two-man Tu-2000A was approximately 150ft (54m) in length, it had a span of 46ft (14m) and an expected take-off weight of about 350 tons (318 tonnes). The aircraft used a conventional heavy-duty tricycle undercarriage and variable cycle engines fuelled with cryogenic methane or hydrogen would provide the propulsion. The performance limit for this prototype was Mach 6. If the Tu-2000A proved successful it would be followed by two developments. The first designated Tu-2000B would be a manned bomber capable of Mach 6 cruise at 100,000ft (30,500m) and having a 6,200 mile (10,000km) range. The overall length of the Tu-2000B would be 328ft (100m), wingspan 133ft (40.7m) and a take-off weight 350 tons (318 tonnes). Propulsion would be provided by six variable-cycle engines running on liquid hydrogen and it is thought that the fuel would be circulated beneath areas of the vehicle's skin for thermal management purposes.

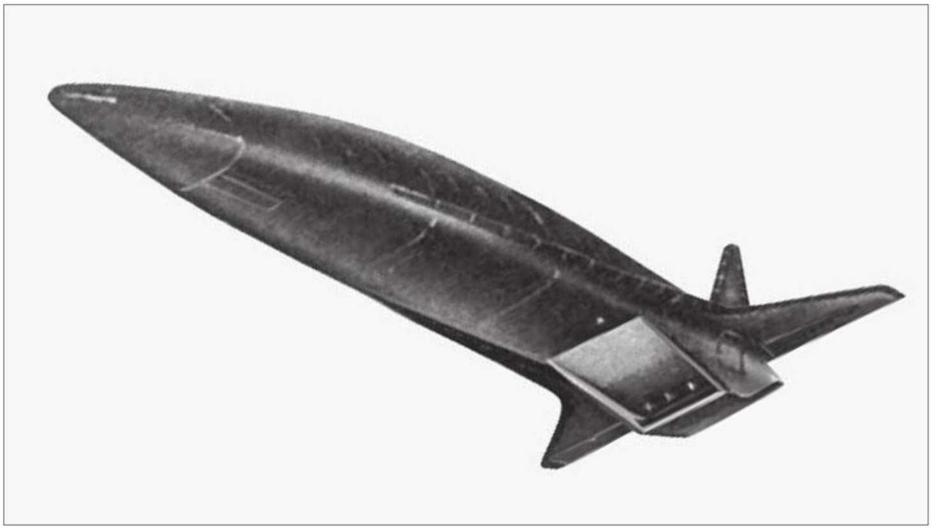
A more advanced and slightly larger version of this design would be the SSTO spaceplane, which would use additional scramjet and rocket propulsion to attain LEO. Both metallic and ceramic panels were considered for heat shielding, with carbon-carbon sections employed in some key areas. Further studies supported by TsAGI (including wind tunnel testing) were carried out and it was decided to begin construction of two Tu-2000A prototypes. Some components (including fuel tanks and supply systems) had been fabricated by the time the programme was cancelled in 1992, once again due to a lack of funding. The claim that at least one titanium airframe was built cannot be substantiated, but is possible.



Two views of a Russian hypersonic vehicle in the NASP class proposed by the VKS and studied by NPO Energia. This SSTO design would have had an overall length of about 219ft (67m) and a span of about 105ft (32m). Propulsion took the form of six advanced variable cycle engines and a LOX/LH2-fuelled rocket engine. NPO Energia via Bill Rose



Drawings, approximately to scale, of spaceplane designs produced by the Tupolev and MiG Design Bureaux. Bill Rose



Artwork showing the initial appearance of the Tupolev Tu-2000 SSTO spaceplane. Tupolev

Korolev's Heavy Space Station

In 1961 Korolev began working on a set of plans for a manned orbital platform called the Heavy Space Station (HSS). This ambitious scheme would be made possible by the use of several N-1 rockets. The HSS was designed for military use to undertake a wide range of surveillance activities and orbital ASAT operations, and might have had the capability to attack surface targets with nuclear missiles. This space platform was envisaged by Korolev as the first in a series of large military space platforms that would orbit the Earth and eventually the Moon. Korolev planned to launch the HSS's core component into orbit with the first test launch of an N-1, which was anticipated in 1965. The N-1 development flights that followed would place two more 50 ton (45 tonne) modules into orbit and these would be coupled to the central core.

Once it was fully assembled, the space station would be slowly rotated to generate artificial gravity in the living sections and electrical power would be provided by a combination of solar panels and a small nuclear reactor. Two of the modules would be used for living quarters and the size of each unit was to be 65ft (20m) in length with a diameter of 14ft 9in (4.5m). The central connecting module would be 39ft (12m) long with a diameter of 13ft 7in (4.15m). This core component would be equipped with four air locks/ docking ports and storage areas for various items of equipment such as space suits. Running through the length of the central module was a 3ft 3in (1m) diameter connecting tunnel that would provide easy access to all essential areas. Additional modules might be added to the central unit if it was decided to enlarge the size of the space station.

Korolev envisaged using small robots with manipulator arms operated under remote control by the crew to undertake external repairs to the station, although this idea appears too advanced for that time. Crew members would be rotated on a monthly cycle, with ferry vehicles also supplying the space station with essential materials and attitude control propellants. The concept came to nothing and the use of the ill-fated N-1 rocket was switched to the Soviet Union's Moon Project. However, many of the basic ideas developed by Korolev in this lengthy series of space station studies would find their way into later projects such as Almaz, Salyut, Mir and the American-sponsored ISS.

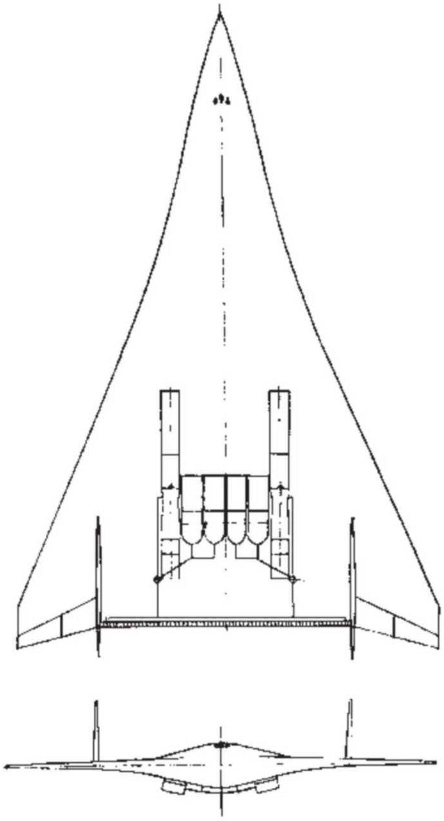
Diamond in the Sky

In late 1963 the American government scrapped its military spaceplane but, as a consolation to the USAF, the politicians decided to proceed with a small manned orbital reconnaissance platform called MOL. This led to a rapid appraisal of American strategy in Moscow and an upsurge of interest in a small military space station under development by Chelomei's OKB-52. This project was proceeding well and a full-sized mock-up of the space station had been completed by March 1964. It was broadly similar to the USAF's MOL and would be used for optical and radar reconnaissance missions. During September 1964 the project was formalised into an outline of proposals for consideration by the Ministry of Defence, and on 12th October OKB-52 was authorised to proceed with full development. The programme was called the Orbital Piloted Station (OPS), it received the reference 11F71 and the codename Almaz (Diamond).

Securing a formal agreement to proceed with Almaz on this date was fortunate, because two days later Khrushchev was deposed and Vladimir Chelomei would rapidly fall from favour through his friendship with the former chairman. In its initial form Almaz was a 20 ton (18 tonne) spacecraft. There were a number of similarities to MOL and it would be launched into orbit carrying a three-seat re-entry capsule called Vozvrashaemiy Apparat (Return Apparatus – VA). VA would utilise a hatch cut into the capsule's heat shield to allow easy access to the space station, rather like the system designed for the American Gemini B. To begin with VA was seen as a good idea, but the plan was finally dropped and it was felt that better use could be made of the space station by ferrying crews to and from orbit in separate vehicles, with Almaz remaining in service for at least two years. A new partly re-usable manned vehicle would be responsible for servicing Almaz space stations and this was also under development by OKB-52. But the time required for development meant that Soyuz spacecraft would initially handle this function.

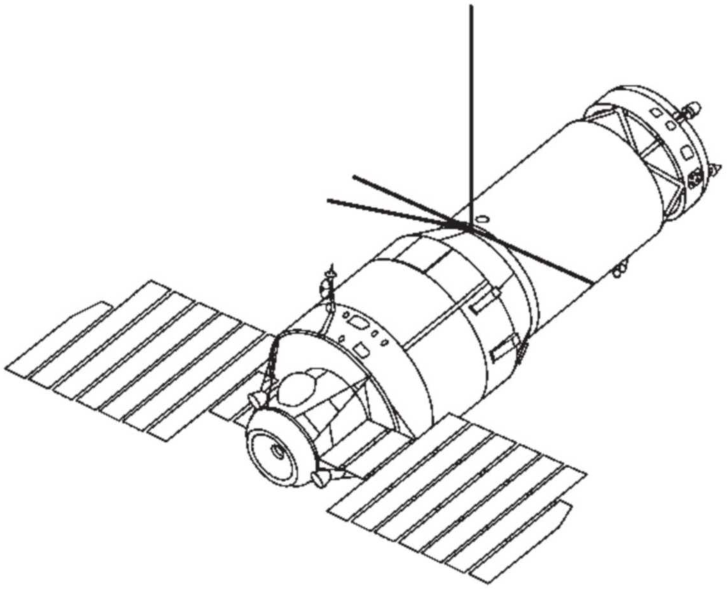
The Almaz space station would have a maximum length of 47ft 9in (14.55m), a maximum diameter of 13ft 6in (4.15m) and a launch mass of 41,800 lb (18,960kg). Electrical power would be generated by two large solar panels with a span of 75ft 5in (23m) and a collecting area of 560ft² (52m²). This would produce just over 3kW. There would also be two small rocket engines to allow orbital correction manoeuvres. The most important item of equipment carried by the space station was a very large telescope using a catadioptric optical system mounted into the wall of the space station. Identified as Agat-1, this high quality hand-built instrument had an aperture of one metre and was capable of imaging surface detail at an equivalent level to the US CORONA spy satellites. Details would be captured on 50cm square film, which is said to have provided a resolution of 100LPM, and the telescope could be made to lock onto a specific area of interest using a spotting scope. A separate optical unit called Volga was also carried for recording surface detail in infrared, although the resolution was much lower than the visible light system.

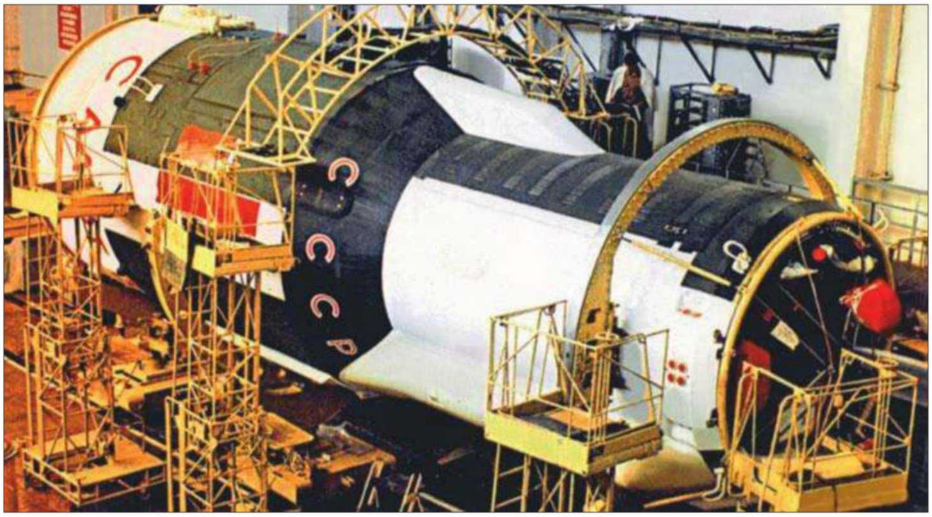
Once photographs had been taken the film could be returned to Earth using a small Information Return Capsule (KSI). This tiny vehicle had a mass of approximately 793 lb (360kg) and a diameter of 2ft 9in (838mm). It was equipped with a miniature solid-fuel de-orbit motor and a heat shield that was jettisoned when the parachute was released. An inflatable airbag was deployed to reduce landing impact and a tracking device was



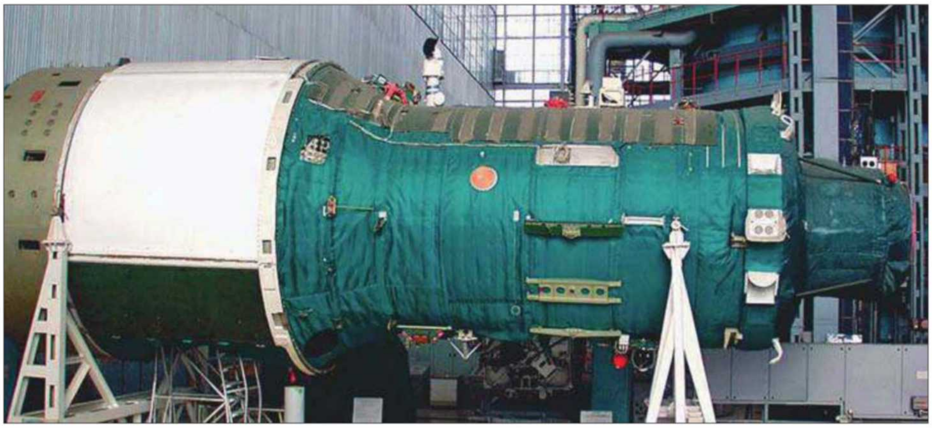
The design of a mixed-propulsion hypersonic vehicle linked to the Tupolev Bureau, which would utilise conventional gas turbines and pulse detonation wave engines. US Patents Office

NASA illustration of Almaz 2. This space vehicle was intended for radar and electronic intelligence gathering but was never flown. NASA





The Almaz (101.2) OPS-2 space station, which used the cover name Salyut 3, shown during final checks at Baikonur in 1974. NPO Mash



Almaz OPS-4 shown here was the last in this series of small space stations, but never reached orbit due to funding problems. NPO Mash

fitted. Alternatively, the film could be processed on the space station, scanned and transmitted to a ground station via a fairly secure downlink. This was probably quite slow as the technology available at that time was relatively crude. As a reminder that Almaz was a military platform undertaking highly classified operations, the vehicle carried a defensive 23mm recoilless cannon in the forward section and the station was equipped with a self-destruct system for last resort use.

Progress with the project was slow because resources were being directed towards the lunar programme, but by 1970 a number of Almaz vehicles had been built for ground tests and two operational Almaz spacecraft were nearing completion at the OKB-52 plant at Krunichev. Chelomei was now instructed to pass the full Almaz specification to the Korolev Design Bureau to facilitate systems integration into its rival DOS project, which would fly as Salyut 1 in 1971. Chelomei's enemies within the State system never missed an opportunity to remind him of past events and this transfer of information to OKB-1 is said to have delayed the Almaz programme by two years. Had Chelomei not occupied such an important role within the country's military-industrial structure, it is fairly clear that Dimitry Ustinov would have swiftly removed him from his directorship of OKB-52.

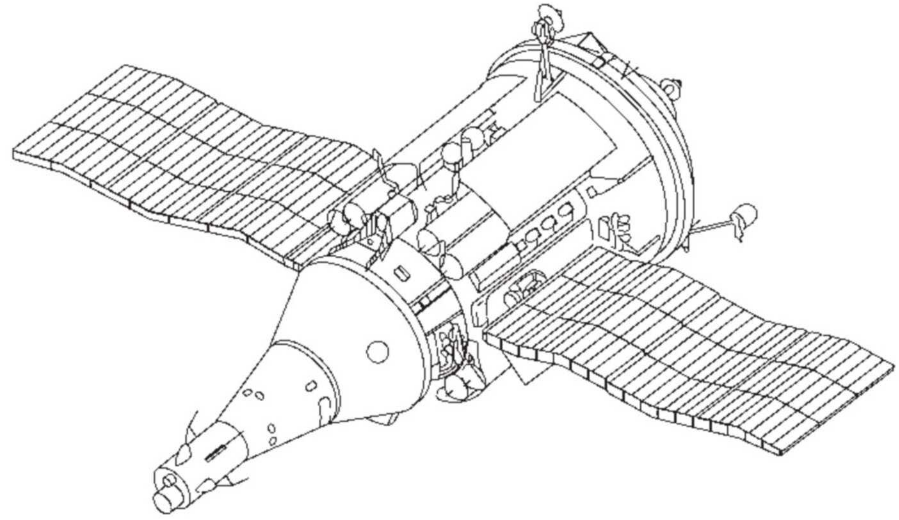
But Chelomei continued to receive support from the Air Force and during 1970 a team of twenty-two cosmonauts headed by Pavel Popovich began training for Almaz operations. Further modifications were made to the Almaz design and there were plans to install side-looking radar, but these were shelved. The first Almaz space station (OPS-1) was finally launched on 3rd April 1973, although it was designated Salyut-2 to conceal the fact that there were two separate space station programmes and this was the military version. But the vehicle was damaged after the upper stage of the Proton rocket suffered a fuel tank explosion and debris punctured the wall of the space station, leading to loss of air pressure. No Soyuz missions were flown to the station and, officially, Salyut-2 completed a series of prearranged tests and was successfully de-orbited on 28th May 1973. The true details of what had taken place would remain secret for several decades.

The second Almaz launch took place at Baikonur on 24th June 1974 as Salyut-3. The first team of cosmonauts arrived at the Almaz space station (designated OPS-2) on 4th July and carried out a variety of survey operations. It is believed that this was a specific military mission and the main areas of interest were in China. In 1969 there had almost been a nuclear exchange between Russia and China following a series of border clashes over disputed territory. An uneasy stalemate followed that remained unresolved until after the collapse of the Soviet Union. A second Soyuz crew lifted-off for Almaz on 26th August 1974 but their rendezvous system failed and they were forced to return, making a difficult landing in the dark. A film capsule is believed to have been automatically ejected from OSP-2 on 23rd September 1974, but no further manned missions were undertaken and Almaz was de-orbited over the Pacific on 24th January 1975.

The third and final Almaz space station (OPS-3), using the cover Salyut-5, was launched on 22nd June 1976. During its period in orbit there were three separate Soyuz missions to Almaz (OPS-3), but the second Soyuz flight failed to dock with the space station. After de-orbit this spacecraft made an unplanned night landing in the semi-frozen Tengiz Lake during a snow blizzard, which prompted a major rescue operation. Almaz OPS-3 finally re-entered the Earth's atmosphere on 8th August 1977 and was destroyed.

Almaz OPS-4 was completed and was fully prepared for the next mission. The optical system was no longer a feature of this spacecraft and had been replaced with radar and ELINT equipment. Amongst the changes was a new docking unit capable of accommodating a TKS spacecraft and a Soyuz spacecraft. It is also reported that the defensive cannon was replaced by small unguided missiles. But this Almaz mission never took place and by the start of 1978 there was little enthusiasm for further manned orbital reconnaissance operations. No money was available for such endeavours with the Buran programme eating up funds.

On 28th June 1978 the manned Almaz programme was officially closed. However, it was decided that the three existing space-



Right: **Designed as an alternative to Soyuz by OKB-52, the TKS spacecraft was specifically produced to support the Almaz military space station.** NASA

Bottom left: **The Vozvrashaemiy Apparat (VA) three-man return capsule (also known as Mercur – Mercury) designed as part of the TKS spacecraft. Although tested as an unmanned system, the TKS was never flown with a crew.** NASA

Bottom right: **A cross-section view of the 20-ton Transportniy Korabl Snabzheniya (TKS) spacecraft designed to ferry personnel and equipment to the Almaz military space station using a Proton rocket.** NASA

craft, which were in various stages of completion, would be converted into unmanned Almaz-T satellites fitted with the Mech-K (Sword) side-looking radar developed by NPO Vega-M. The first launch was planned for 1981 but was cancelled on the grounds of cost. The three spacecraft were then placed in storage until 1985 when Chelomei's successor Gerbert Efremov managed to have the Almaz-T programme re-started. The spacecraft were now modified by removing the unnecessary docking system and the first Almaz-T was launched from Baikonur on 29th October 1986, but the second stage of the Proton rocket failed to separate and the vehicle was destroyed

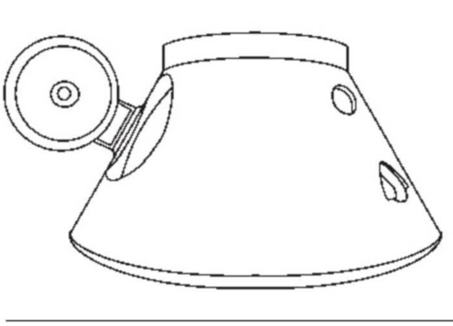
On 27th July 1987 the second Almaz-T was successfully launched into a high inclination 71.92° orbit. Identified as Cosmos-1870, it stayed in orbit until 30th July 1989. The third Almaz-T was launched on 31st March 1991 using the name Almaz-1. There were a number of technical problems but it is believed that the satellite managed to return useful data before it was de-orbited on 17th October 1992. A follow-on Almaz-2 was planned with more advanced electronics and a radar system capable of resolving detail as small as 16ft (5m). However, the Soviet Union was no longer in existence and the country was in financial chaos, so the programme was abandoned.

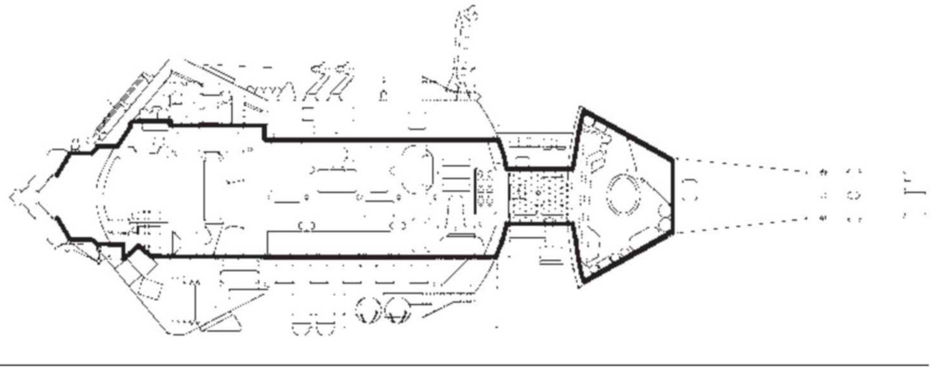
TKS Spacecraft

In the early 1960s OKB-52 designed an alternative to the Soyuz which was specifically intended to ferry personnel and equipment to the Almaz military space station using a Proton rocket. The 20-ton (tonne) Transportniy Korabl Snabzheniya (TKS) spacecraft was made up of a cargo section, usually called the Functional Cargo Block or FGB, and a Vozvrashaemiy Apparat (VA) return capsule for three crew members. The VA capsule was originally designed to be launched as a component of the TKS spacecraft, or with the Almaz space station, using a hatch in the heatshield like the American Gemini B. As an independent vehicle the VA could operate in space for thirty-one hours while carrying three cosmonauts and it was designed to return as much as 110 lb (50kg) of cargo from Almaz. The TKS spacecraft had an overall length of 42ft 7in (13m) (with its VA capsule) and a pressurised volume of 1,762ft^3 (49.88m^3). It diameter was 13ft 7in (4.15m) and the launch mass was approximately 47,663 lb (21,620kg).

Six TKS spacecraft had been completed by the start of 1977, but continuation of the Almaz programme was now becoming increasingly doubtful. However, the first unmanned TKS launch was undertaken on 17th July 1977 using the cover name Kosmos-929, and the spacecraft was still being considered for manned missions to future Salyut stations. A further three unmanned missions were conducted which docked with Salyut-6 and Salyut-7 between 1981 and 1985. Four separate VA capsule tests were also undertaken. The TKS was never flown as a manned spacecraft, although it was used as the basis of various successful Mir components and the Zarya (Sunrise) module, which was selected as the primary component of the ISS.

Manufactured at Krunichev for half the price of Lockheed's proposed Bus-1, the module (referred to in Russia as FGB-1) was purchased by NASA for $220 million and launched at Baikonur on 20th November 1998. One other development of the TKS was the Polyus, which was designed as a prototype orbital weapons platform.





Polyus

In 1983 President Ronald Reagan announced the development of a shield in space to protect the United States from nuclear missile attack. The Strategic Defence Initiative, soon christened Star Wars by the media, was hugely ambitious, phenomenally expensive and ultimately unworkable, but it triggered immediate alarm bells in the Kremlin. As a consequence, Chairman Yuri Andropov authorised the production of systems to match and counter the US proposals.

One particular design for an experimental orbital combat station was called Polyus (Pole), or Skif-DM, and was designed to test a variety of new technologies. The design originated with Chelomei's bureau and was based on a TKS-derived module originally intended to serve as the first component for the proposed Mir-2 space station. Normally Soviet space projects were undertaken on a five-year basis, but it seems that Polyus was pushed forward by the leadership who wanted quick results in their quest to keep pace with the Americans.

Andropov died in February 1984 and his successor, Konstantin Chernenko, continued to support the development of new Soviet space weapons. However, Chernenko was suffering with emphysema and died the following year, so it seems probable that others such as Ministers Oleg Dmitriyevich Baklanov and Oleg Shishkin were shaping events. They had jointly approved the assembly of Polyus at the Krunichev facility on 1st July 1984 and took overall control of the project. After Chernenko's death on 12th March 1985, his successor Mikhail Gorbachev attempted to halt the development of space weapons, but he also made it clear to the US administration that the Soviet Union would respond directly to Reagan's Star Wars programme if it continued to gain momentum. Gorbachev believed that the pursuit of space weapons could prove destabilising.

In July 1985 it was agreed to launch a Polyus test vehicle by September 1986. With the development of the Energia booster moving ahead quite rapidly, a decision was taken to launch Polyus as part of the first test flight, although adapting the spacecraft to Energia was proving rather difficult. The Polyus vehicle was 121ft (37m) in length, it had a diameter of 13ft 4in (4.10m) and a mass of 176,369 lb (80,000kg). The intention was to launch the spacecraft into a 173-mile (280km) orbit with a 64° inclination. The Polyus spacecraft carried a range of experimental military technologies designed for offensive and defensive use. Prototype weapons included a cannon that used a gas exhaust system to counter recoil and a chemical laser, which probably lacked sufficient power to vaporise targets but certainly had the ability to destroy optical sensors. A passive optical system was used to aim both of these systems (which was supported by radar) and a third weapon described as a nuclear mine dispenser also appears to have required the use of counter-recoil measures. It was also planned to determine the effectiveness of releasing barium clouds to diffuse the beams of Directed-Energy Weapons (DEWs) because this was considered to have good potential as a defensive measure.

Polyus would utilise secure radio data links, but another technology being tested was laser communication which avoided the possibility of eavesdropping or jamming. One other experiment involved stealth technology and the entire vehicle was covered in a matt black radar-absorbing paint. During the trials personnel on the ground, on ships and aboard aircraft would attempt to locate and track the spacecraft by visible, infrared and radar means. If it was detected, they would direct lasers towards Polyus and the beam would be reflected back to Earth by an onboard mirror. Under considerable pressure the engineers at NPO Mash completed work on the Polyus prototype and it was delivered to Baikonur on schedule during August 1986. It had been a massive effort to override the slow methods of working in the Soviet Union, compounded by the involvement of several major subcontractors who included NPO Digital Mechanics, NIIMASh, NPO Elektropribor and NPO Radiopribor. The spacecraft now underwent a lengthy series of tests and checks which were completed at the end of January 1987.

Apparently Gorbachev visited Baikonur during this period and expressed serious reservations about the project, believing it might send the wrong signals to the West about Russia's intentions in space. Despite this the launch went ahead on 15th May 1987 and the Energia booster performed faultlessly. But there had been major difficulties adapting Polyus to Energia and engineers were forced to install boosters in Polyus's nose. This meant that the spacecraft had to perform a 180° yaw manoeuvre after separation. Moments after Polyus detached, an inertial guidance sensor malfunctioned and the spacecraft was turned through 360° before engine ignition, causing it to crash into the South Pacific Ocean. Apparently several technicians lost their jobs as a result of this incident, and there were no attempts to build a second Polyus or to initiate work on the proposed Mir-2 space station. The existence of this project has only recently come to light and how much the CIA knew about Polyus remains unknown.

The Soyuz as a Military Spacecraft

Although not immediately associated with military operations, the Soyuz (Union) spacecraft was designed as a versatile system with the potential to undertake a wide range of missions, including military tasks. Draft proposals for a larger multi-purpose manned spacecraft to follow Vostok were produced by Sergei Korolev in 1962. The new vehicle would be capable of orbital operations, with the potential for a circumlunar mission if funding permitted. Korolev also proposed two little-known military variants of the Soyuz spacecraft called the Soyuz-(7K)P Perekhvatchik (Interceptor) designed for manned ASAT operations and the larger Soyuz-(7K)R Razvedki (Intelligence) to be used for reconnaissance missions. Soyuz received official approval for further development in 1963 and the Air Force was enthusiastic about these military versions. But OKB-1 was working at full capacity and a decision was finally taken to pass the military Soyuz projects to an OKB-1 division located at Samara known as Filial (Branch) 3, which was headed by Dmitri Ilyich Kozlov (1919-?).

Kozlov had played a major role in developing the R-7 rocket and was largely responsible for turning the original manned Vostok capsule into a useful photo-reconnaissance

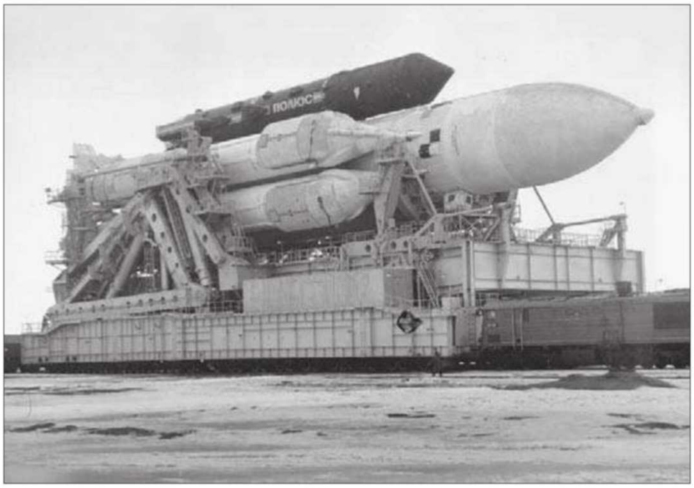
Right: **Another view of Polyus and its Energia launch vehicle on their way to the launch pad at Baikonur. Polyus was designed to test various newly developed offensive and defensive weapons in space.** RKK Energia

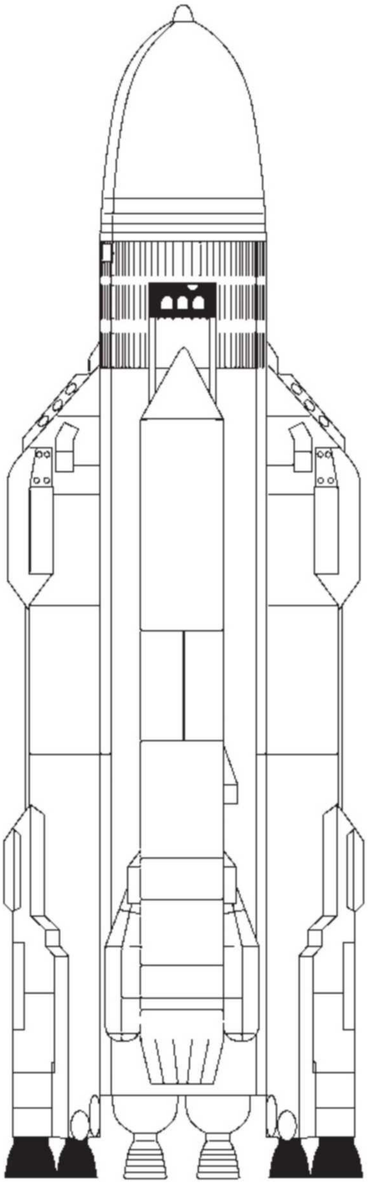
Below, far left: **Illustration produced by NASA of the Polyus and Energia launch vehicle. It seems fairly apparent that the Americans were unaware of Polyus's true purpose at the time it was launched.** NASA

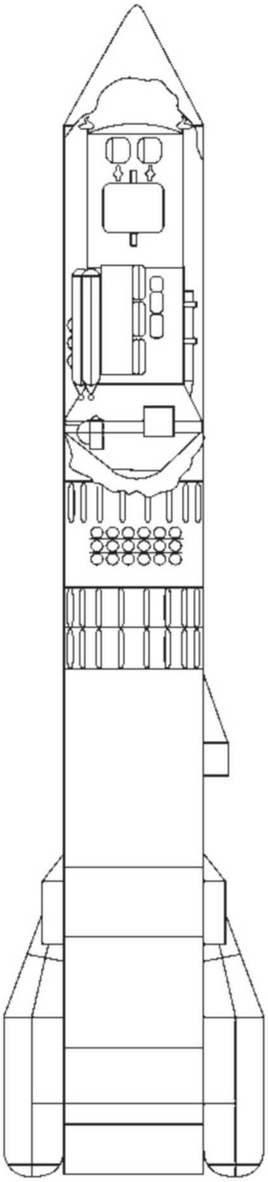
Below, left: **Russian drawing showing some of Polyus's internal structure.** RKK Energia

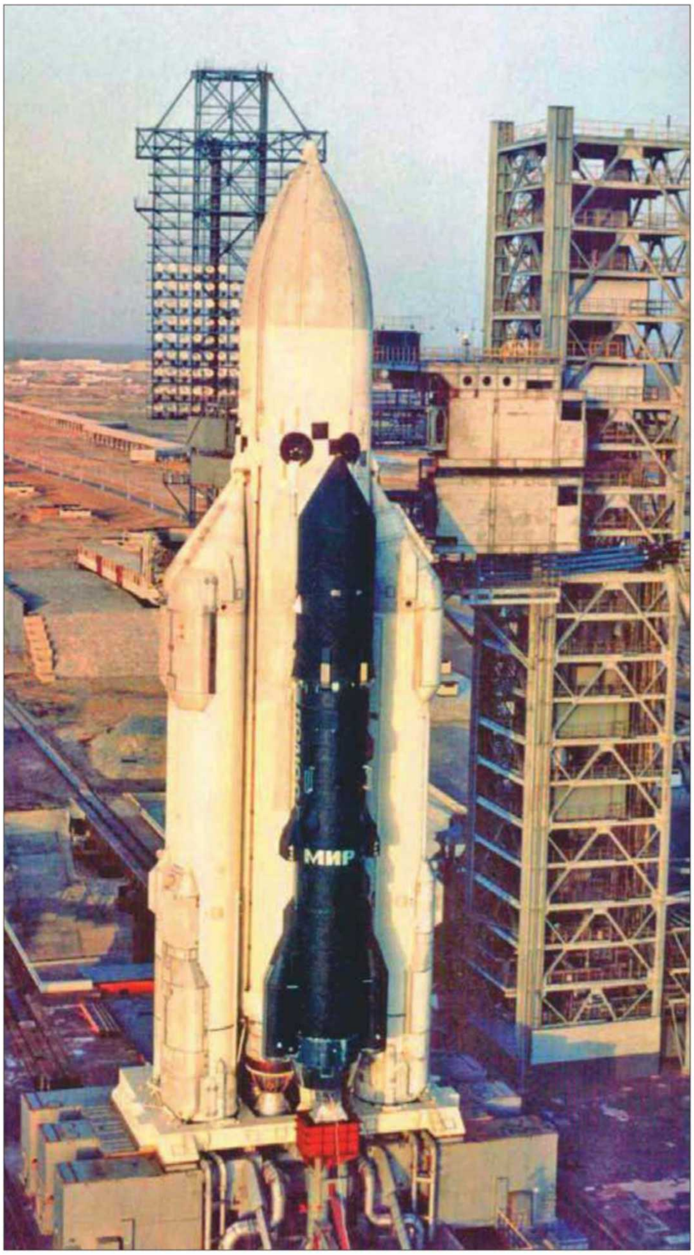
Below right: **Polyus is prepared for lift-off on 15th May 1987. The Energia booster performed perfectly but technical problems with the Polyus led to a launch failure.** RKK Energia

Opposite page:
A Russian-built Zarya (Sunrise) module photographed from STS-88. Based on the TKS design, this type of unit would form a core component of the International Space Station (ISS). NASA









satellite called Zenit-2. Filial 3 was already working on an improved Zenit-4 reconnaissance satellite carrying a more efficient optical system, so this large subsidiary of OKB-1 was the ideal choice for a military Soyuz programme. Work on the military Soyuz designs began in 1964 and it was initially proposed that Soyuz-P would rendezvous with a foreign satellite and one of the cosmonauts would leave the vehicle to conduct a physical inspection. The satellite would then be incapacitated, destroyed or (depending on its size) returned to Earth for inspection. All these proposals were immediately rejected by the military as being too risky, which believed that foreign military satellites would be booby-trapped in the same way as Soviet spacecraft. A modified design called 7K-PPK (Pilotiruemiy Korabl-Perekhvatchik) was then suggested would have the ability to inspect and destroy enemy satellites from an approximate distance of 0.6 mile (1km). It would be armed with eight unguided rocket-mines.

The two-man vehicle would have a length of 21ft 4in (6.5m), a maximum diameter of 9ft (2.75m) and a projected mass of 14,700 lb (6,700kg). It would be attached to a Soyuz-B rocket stage for orbital manoeuvring and make use of the Soyuz-V tanker for refuelling. ASAT operations were considered possible at orbits as high as 3,700 miles (6,000km). The larger two-man Soyuz-R would be assembled from two separately launched vehicles that would dock in orbit. This would produce a total length of 49ft (15m), it would have approximately the same maximum diameter and a combined mass of 13 tons (11.8 tonnes). The Soyuz R station section was designated R-11F71 and the second transport craft that docked with the Soyuz R and delivered the crew was called the 11F72 Soyuz 7K-TK. Both vehicles would be launched using modified R-7 rockets. Soyuz-R was expected to undertake daylight photo-reconnaissance and ELINT missions but on 30th March 1966 the project was cancelled. However, it was decided that Soyuz 7K-TK would now be used to ferry personnel and supplies to the Almaz space station.

At about the same time development of the Soyuz PPK was halted, with preference being given to OKB-52's unmanned Istrebitel Sputnikov (Destroyer of Satellites) which was considered more cost effective. Despite these changes Kozlov's Division continued to work on designs for Soyuz military spacecraft. This led to the Soyuz VI (not Soyuz-6) vehicle which had entered construction by the late 1960s and was conceived as a military test vehicle. The design of Soyuz VI went through a number of changes, with the final version resembling the original Soyuz R configuration. An initial test flight was planned for early 1969 and the military was anxious to have the craft in orbit before the American MOL, but it was cancelled in 1968 when Almaz became the favoured option for a small manned military space platform.

Russian ASAT Weapon Development

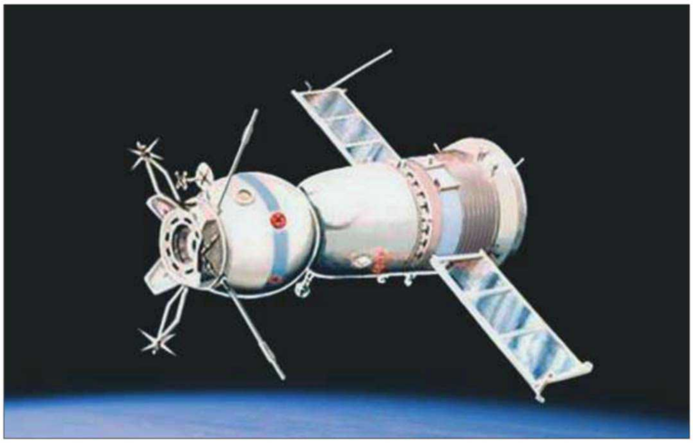
Although the Soviets considered a highly modified Soyuz spacecraft and several small spaceplanes for manned ASAT operations, most of the effort in this area was directed towards the simplest, cheapest and most effective systems, which meant rocket-launched automated vehicles. The development of anti-satellite weapons began soon after the start of the Space Race and intensified as the US began to field an increasing number of photo-reconnaissance satellites during the 1960s. Today satellites are regarded as key military assets. They provide high-resolution imagery of inaccessible territory which can be relayed to base in near real-time. Satellites can also be used to track the movements of aircraft and ships or observe the launch of missiles. They are able to detect the unique signatures of atmospheric nuclear explosions and represent the front line against any surprise attack. Satellites in orbital or geostationary orbits can also be used to eavesdrop on a various forms of communication and act as important data relay platforms. Other essential technologies for the military are accurate weather observation and more recently Global Positioning Systems (GPS).

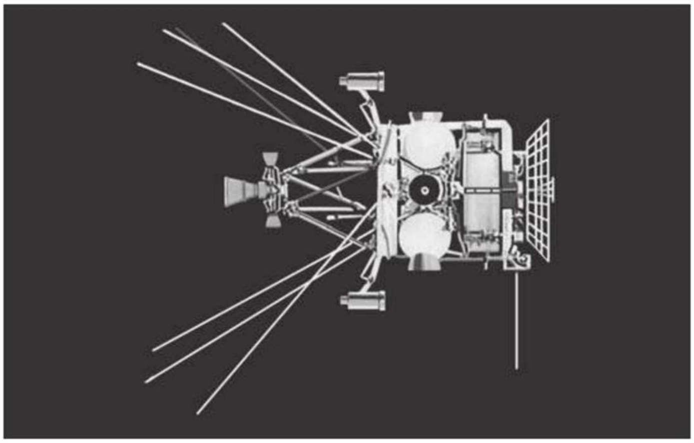
However, these important abilities have made orbital vehicles prime targets for attack in any high-priority covert operation or major conflict, and this fact was recognised decades ago. Once the US and Soviet Union agreed to the Strategic Arms Limitation Treaty (SALT I) in May 1972, the testing of anti-satellite weapons moved into the background and outwardly appeared to have been abandoned. All the same the Soviet Union, like many other nations, has a history of saying one thing and secretly doing another. This was the case with the Biological Weapons Convention of 1972 which Russia signed while initiating a full scale deep-black bio-warfare programme called Biopreparat, which remained completely hidden from the West until a high-level defection took place in 1989. Similarly, throughout the 1970s the Soviet Union continued to develop and refine anti-satellite systems under the cover of other programmes, and by the end of that decade it was starting to take a serious interest in ground-based Directed-Energy Weapons (DEWs) as a means of disabling and perhaps destroying enemy satellites. Claims that US reconnaissance satellites had been attacked with DEWs started to appear in the press from the late 1970s onwards, but there was never any official comment on this from either side. Relatively little is known about similar research programmes in America, although considerable effort has been expended on the development of US ground-based and space-based lasers.

Left: **Russian Soyuz spacecraft in orbit.** NASA

Opposite, top left: **Artwork showing a Russian two-man Soyuz spacecraft modified to intercept, inspect and destroy foreign satellites.** Bill Rose

Opposite, top right: **The Russian satellite destroyer known as 'Istrebitel Sputnikov' (IS). Carrying an explosive charge, it would be guided on an intercept course towards enemy satellites.** Bill Rose





The massive US effort during the 1980s to produce advanced weapons under SDI had a direct impact on Soviet military planning, and it has been argued that part of the American strategy was to push the Russians into a new, financially crippling arms race they could never win. The need for each side to match and counter new weapons continued until the arrival of economic chaos in the Soviet Union. Perhaps the Americans always knew that their SDI goals were largely unattainable and by the start of the 1990s the grand ambitions for a shield in space were beginning to fade. Some new technology developed during the SDI programme was showing promise, such as battlefield lasers and electromagnetic railguns, but the overall concept of protecting America from a nuclear missile attack remains unrealistic. The final SDI proposal was to build an orbital system called Brilliant Pebbles which had been envisaged in the early 1960s. Brilliant Pebbles took the form of forty orbital platforms equipped with 1,500 kinetic interceptors derived from ASAT weapons. The Americans planned to steadily improve the capability of this system but Brilliant Pebbles was cancelled in 1994 when it was no longer considered necessary.

By this time the development of new US and Russian space-based weapons systems had virtually come to a halt, but there has been something of a recent revival in America with the attempts to deploy a small scale system called National Missile Defense (NMD) to protect all fifty US States from missiles built by rogue regimes. The technological requirements to make NMD effective remain substantial, despite advances in tracking, guidance and the ability to deal with countermeasures. NMD has been viewed with considerable suspicion by the Putin Administration in Russia, who approved upgrades of the solid-fuel SS-27 Topol (Poplar) M missiles from a single warhead to six re-entry vehicles. Each of these carries a 550 kiloton yield warhead and is capable of hypersonic manoeuvring to evade interception.

The IS System

America's ability to gather intelligence on Soviet developments was severely limited during the early post-war years and the only methods of aerial observation available were large numbers of camera-equipped balloons and specialised spyplanes. The balloons were uncontrollable, unreliable and generated serious diplomatic problems, while the high-altitude reconnaissance flights ended on 1st May 1960 when a Lockheed U-2 was shot down and the pilot captured. There was now intense pressure on US defence contractors to provide the USAF and CIA with a reconnaissance satellite system, and there was an equal determination within the Soviet Union to counter US satellite observation of its activities. Vladimir Chelomei is generally credited within Russia as being the first designer to suggest the idea of an anti-satellite system using another small space vehicle carrying an explosive charge. His initial proposal for an Istrebitel Sputnikov (IS – Destroyer of Satellites) was made in 1959. This small vehicle would be directed towards the target from the ground before it switched to its own terminal guidance system.

In early 1960 Khrushchev approved development of the UR-200 ballistic missile which Chelomei had suggested as the launcher for his IS satellite destroyer, and a decision to proceed with the IS was approved in early 1961. This project was assigned to Anatoly Savin and his deputy K A Vlasko-Vlasov, who ran a group within OKB-52 called KB-1. Much of the work on the IS appears to have been compartmentalised and classified as top secret. As the first prototypes neared completion in 1963, there were still problems with developing the UR-200 and a formal request was made via official channels to secure the use of R-7 launch vehicles for testing. The first two prototype test vehicles, named Polet (Flight), were launched on 1st November 1963 and 12th April 1964. Both lacked radar and infrared homing systems but successfully demonstrated orbital manoeuvring capabilities. But the UR-200 missile intended to launch IS still proved very troublesome and after the second test it was cancelled. However, the Ministry of Defence was sufficiently impressed with IS to recommend that the launch vehicle should be replaced by an R-36 missile (SS-9 NATO *Scarp*) then under development by OKB-586. This resulted in OKB-586 receiving a formal request in August 1965 to develop a suitable version of the R-36 as an IS launcher, and the new slightly modified design was designated 11K67 (and later Tsyklon-2A).

The test launch of this rocket carrying the third prototype IS vehicle took place at Baikonur on 27th October 1967 and was judged to have been a success. Named Cosmos-185, the IS spacecraft initially entered a 339 x 229 mile (546 x 370km) orbit with a 64.1° inclination, which was later boosted to a 550 x 324 mile (888 x 522km) orbit. During April 1968 another IS vehicle was launched at Baikonur as Cosmos-217, although something went wrong with this test and the IS failed to separate from the upper stage. Six months later Cosmos-248 was launched into orbit at Baikonur as a large target satellite for a full-scale test of the IS vehicle's capability. Within a matter of hours Cosmos-249 had been launched which was a fully equipped IS vehicle. Cosmos-249 attained a 157 x 84 mile (254 x 136km) orbit and manoeuvred to pass within close proximity of Cosmos-248. A small explosive charge was then detonated to demonstrate the system, although the target vehicle is thought to have remained largely undamaged.

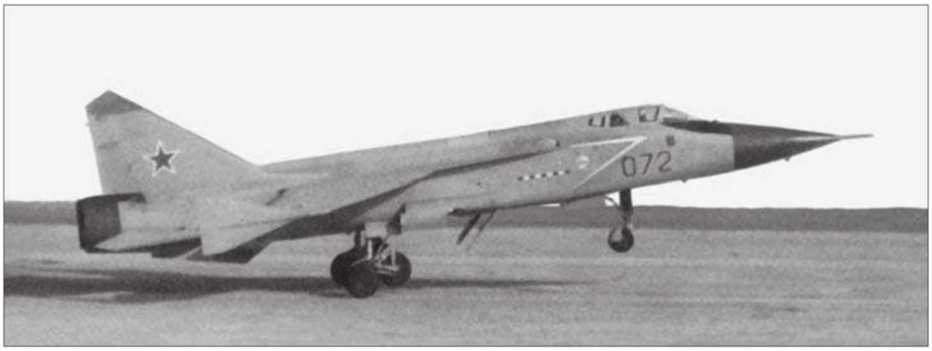
Less than two weeks later another IS vehicle designated Cosmos-252 was launched and successfully intercepted Cosmos-248. The spacecraft exploded within close proximity of the satellite and it was completely destroyed. Although the IS system was still in its early test phase, it seems reasonable to conclude that these trials were considered very successful. Further launches took place during 1969 and 1970 with the orbital apogees of the vehicles increasing to more than 1,242 miles (2,000km) before descent to the target. During 1971 several target satellites designated DS-P1-M were launched from Plesetsk and ASAT trials continued until 1972 when SALT 1 was signed. However, it seems that the Soviet anti-satellite system was considered semi-operational by this time.

Tests resumed in 1976, possibly as a response to military proposals for the US Shuttle which the Soviets perceived as an offensive weapon. It was also clear that the capability and accuracy of the IS system continued to improve. Development of this programme proceeded rather erratically until 1983 when Chairman Yuri Andropov decided to halt further ASAT trials for political reasons. Although ASAT research continued and the Polyus orbital platform was built and unsuccessfully launched in 1987, no further tests were undertaken. Just how far the US went with attempts to duplicate the Soviet IS system remains unknown, but Project SAINT may have been conceived as a direct response to IS.

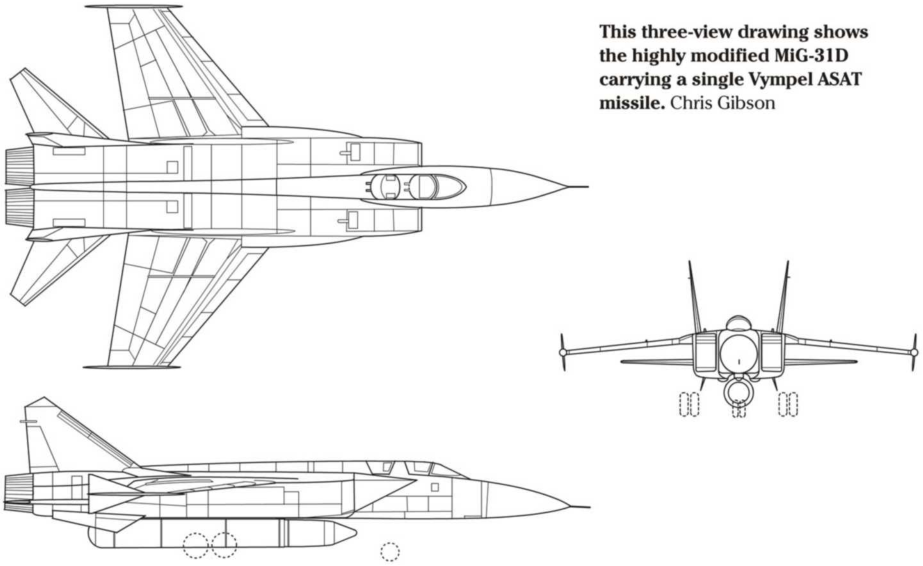
Air-Launched ASAT Missiles

A short-lived Soviet project to test the feasibility of air-launched ASAT missiles may have been undertaken during the 1960s, but no reliable details are available at present. In 1986 two extensively modified Mikoyan MiG-31D *Foxhound* interceptors (071 & 072) were completed for the specific purpose of launching ASAT missiles. The concept was broadly similar to the USAF's F-15 ASAT programme and it provided a flexible and less expensive alternative to ground launched ASATs for engaging high-flying manned spaceplanes and targets in LEO. Some of the modifications to the MiG-31s included replacement of the forward radar system with ballast (although a new upward-looking system was planned for later installation), removal of the aircraft's cannon and a smooth underside with a pylon for the single missile. Winglets were also fitted to improve stability during missile launch. Test flights are known to have been conducted at Zhukovsky with an inert missile and there are unverified claims that a number of live missiles were launched at the Sary-Shagan anti-ballistic missile test site between 1987 and 1991.

Launches of the Vympel ASAT weapon would have been made during a supersonic climb to high altitude and the missile's small payload would have killed its target with the force of impact. The ASAT system was cancelled in 1991, although there have been recent attempts to revive this project as a commercial satellite launch system. Both MiGs are currently stationed in Kazakhstan and discussions have taken place between the Kazakhstan government and Russian aerospace companies to utilise these aircraft to launch small commercial payloads of 220 lb (100kg) into 124-mile (200-km) orbits, or smaller 154 lb (70kg) payloads into 310-mile (500-km) orbits.



Two of these aircraft were modified to carry ASAT missiles capable of engaging targets in LEO and possibly sub-orbital hypersonic vehicles, but the project was scrapped in the early 1990s. MAP



This three-view drawing shows the highly modified MiG-31D carrying a single Vympel ASAT missile. Chris Gibson

SOVIET/RUSSIAN BALLISTIC MISSILE DESIGNATIONS (Land Launched)

US	NATO	Soviet/Russian	Design Bureau
SS-1A	Scunner	R-1	German/Korolev
SS-1B	Scud A	R-11	Korolev (OKB-1)
SS-1C	Scud B	R-17	Makeyev (SKB-385)
SS-1D	Scud C	KY-3	Makeyev
SS-2	Sibling	R-2	Korolev
-	-	R-3	Korolev
SS-3	Shyster	R-5	Korolev
SS-4	Sandal	R-12	Yangel (OKB-586)
SS-5	Skean	R-14	Yangel
SS-6	Sapwood	R-7	Korolev
SS-7	Saddler	R-16	Yangel
SS-8	Sasin	R-9	Korolev
SS-9	Scarp	R-36	Yangel
SS-X-10	Scrag	UR-200	Chelomei (OKB-52)
SS-11	Sego	UR-100	Chelomei/ Machine Prod
SS-12	Scaleboard	9M76	Votkinsk (Moscow IT* Plant)
SS-13	Savage	RT-2	Moscow IT
SS-X-14	Scamp	RT-15	
SS-X-15	Scrooge	RT-20	Moscow IT
SS-16	Sinner	RS-14	Moscow IT
SS-17	Spanker	MR-UR-100	Yangel
SS-18	Satan	R-36M	Yangel
SS-19	Stiletto	UR-100N	Chelomei
SS-20	Saber	15Zh-45	Moscow IT
SS-21	Scarab	9M79	Machine Prod
SS-22	Scaleboard†	9M76	
SS-23	Spider	9M714	
SS-24	Scalpel	RT-23	Moscow IT/ Southern MDB
SS-25	Sickle	RT-2PM	Moscow IT
SS-26	Stone	9M72	
SS-27	-	Topol M	Moscow IT
SS-X-28	Saber	15Zh53	
SS-29	‡	Topol M	Moscow IT

* Moscow Institute For Thermal Technology
† SS-22 Re-designated as SS12B
‡ Multiple Warhead Version of SS-27

Chapter Six

Nuclear Propulsion

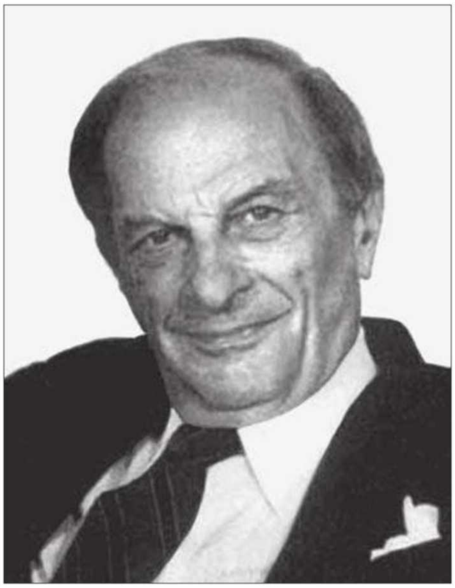
American Efforts

The possibility of using atomic energy for space propulsion was suggested by the American rocket pioneer Robert Goddard just before World War One and the idea was revived by Esnault-Pelterie in the early 1930s. Although atomic rocket power remained largely confined to the world of science fiction for the next decade or so, it resurfaced in 1944 as a serious topic of discussion amongst scientists working on the Manhattan Project (America's first atomic bomb). Two members of this elite group were Stanislaw Ulam (1909-1984) and Frederick de Hoffman (1924-1989), who both started to look at ideas for applying nuclear energy to rocket propulsion. This resulted in plans for a very different type of engine that didn't burn fuel with an oxidant in a combustion chamber. Instead, a propellant (typically hydrogen) would be pumped into a very hot, moderated uranium reactor and this sudden heating would immediately boost the fuel's energy content. As such it would emerge as a powerful propulsive jet.

In 1945 ARPA became involved with nuclear rocket propulsion concepts and issued contracts to several US defence companies for secret studies (ARPA stood for the Advanced Research Projects Agency, which later became DARPA when the word Defense was added). Submissions from Douglas Aviation were regarded as the most promising, but relatively little further research was conducted until Robert Bussard took a fresh look at the nuclear thermal engine in 1953. He finally concluded that not only was the idea of an atomic rocket engine feasible, but previous performance estimates were somewhat pessimistic. This report generated a wave of enthusiasm within the Pentagon and senior officials were soon pushing for new research to meet the propulsive needs of future manned spacecraft and ICBMs capable of carrying thermonuclear warheads (which were substantial in size at that time) over global distances. Plans had already been drawn up to build large liquid-fuel boosters with the provisional names Saturn and Nova, and these giant rockets might be further enhanced if nuclear upper stages were added.

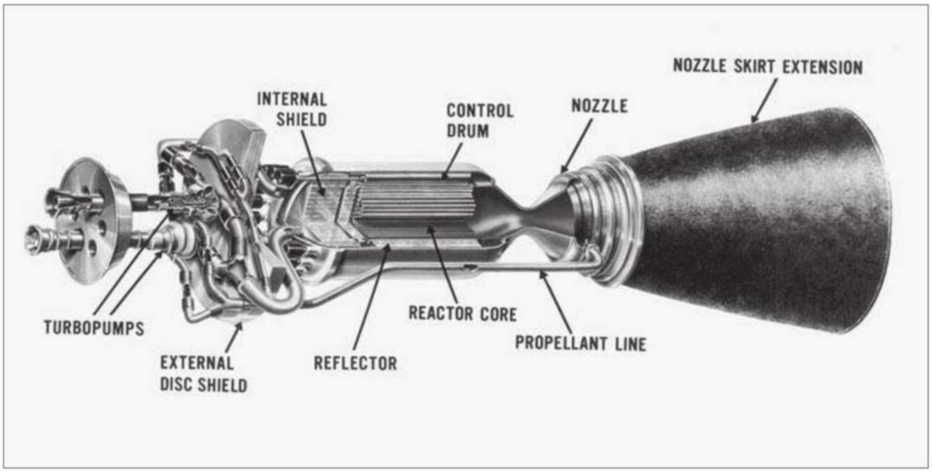
With serious concerns about the Soviets stealing a lead in this area, funding was made available to initiate a project called Nuclear Engine for Rocket Vehicle Applications (NERVA). NERVA began on 1st June 1955 and led to an initial series of detailed assessments carried out at the Los Alamos Scientific Laboratory. This development programme then received the new name Project Rover and scientists produced schematics for a nuclear engine that used uranium carbide for reactor fuel within a graphite core that functioned at 5,432°F (3,000°C). Westinghouse and Aerojet were selected as the prime contractors and construction of the first prototype atomic engine had started by the late 1950s with a series of trials scheduled at Area 25 within the Nevada Test Site, which is a remote valley better known as Jackass Flats.

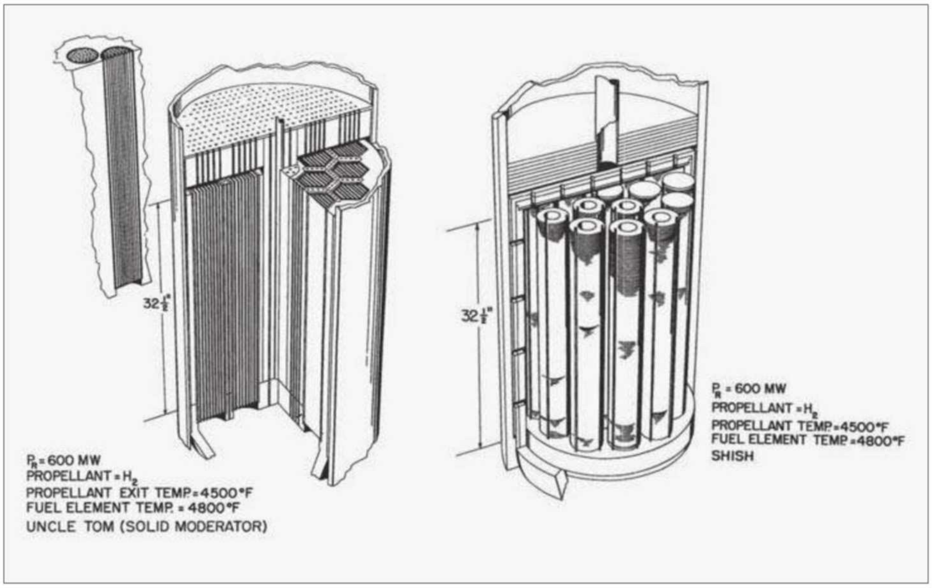
The first engine test of a design called Kiwi-A took place during July 1959 and the name Kiwi was chosen because it referred to a flightless bird. But difficulties were encountered when the reactor temperature reached 4,369°F (2,409°C) and major vibration problems set in, causing serious damage to the core. Kiwi-A underwent significant modification but the problems persisted, although the concept was shown to be viable and valuable lessons were learnt. In May 1961 President Kennedy took the advice of his scientific team and decided that funding should be maintained for nuclear propulsion. While the Pentagon considered nuclear propulsion promising, NASA officials were less enthusiastic about the technology. They considered it dirty and dangerous, but finally accepted that it would be necessary for interplanetary missions.



Above: **While working on the wartime Manhattan Project, Stanislaw Ulam (shown in this photograph) and Frederick de Hoffman developed the first proposals for atomic rocket propulsion.** US Department of Defense

Below: **Schematic of a later NERVA design circa 1970.** NASA

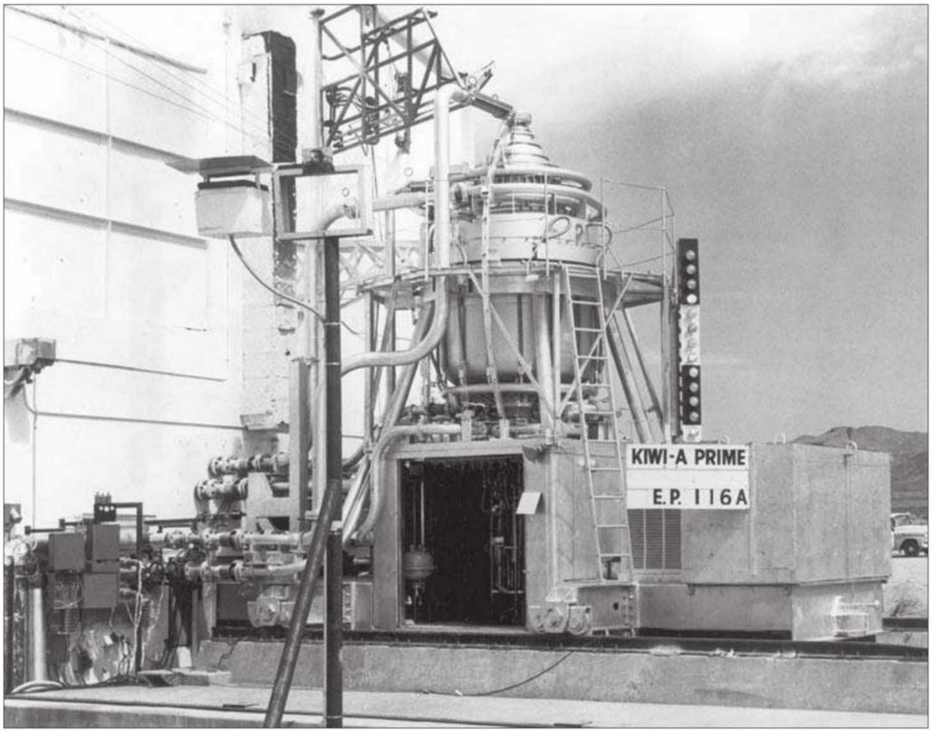



32½"
P_R = 600 MW
PROPELLANT = H_2
PROPELLANT EXIT TEMP = 4500°F
FUEL ELEMENT TEMP. = 4800°F
UNCLE TOM (SOLID MODERATOR)
32½"
P_R = 600 MW
PROPELLANT = H_2
PROPELLANT TEMP = 4500°F
FUEL ELEMENT TEMP = 4800°F
SHISH

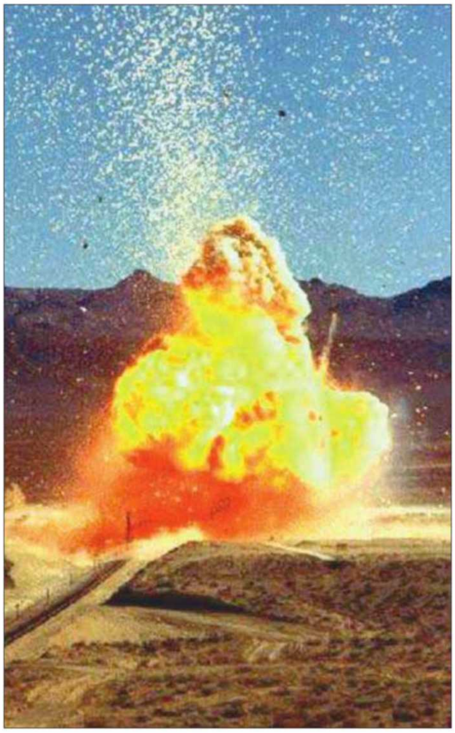
Left: **Two different fuel core designs used within the Kiwi test engine.** US DOE

A series of experimental Kiwi reactors followed which were used to test a variety of different materials and engineering methods with varying degrees of success. This part of the NERVA programme lasted until January 1965 when a Kiwi reactor (Kiwi-TNT) was deliberately blown up during a simulated launch to test reactor shutdown procedures in a 'worst case' power transient event. This released a radioactive cloud that drifted across parts of Los Angeles and finally dispersed over the Pacific Ocean, prompting Soviet Ambassador Anatoly Dobrynin to request details from the Department of State about what had taken place. In a confidential document the Americans replied, 'The position of the United States Government is that the Kiwi experiment did not constitute a "nuclear explosion" within the meaning of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water. The experiment was a reactor safety test and its technical characteristics are readily distinguishable from a nuclear explosion.'

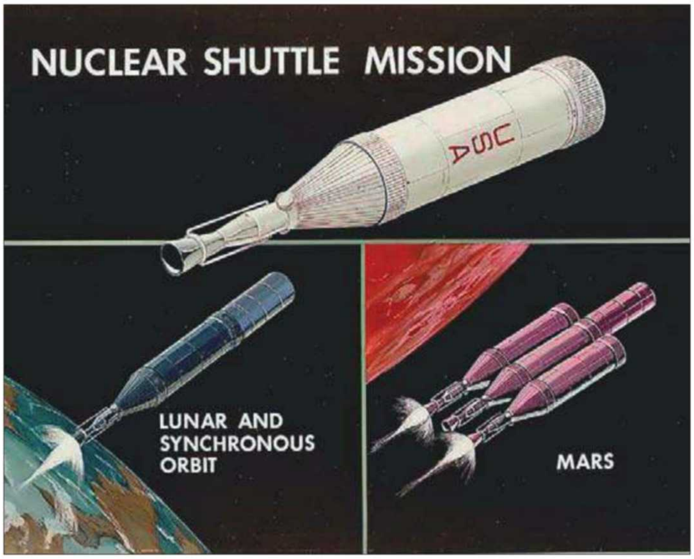
But the Kiwi-TNT event clearly ruffled feathers and the details resurfaced many years later in the mid-1990s when political representations were made to the Secretary of the Department of Energy by Massachusetts Democrat Congressman Edward Markey. He said that, 'an intentional reactor accident releasing a radioactive cloud should not be considered prudent public policy'. Markey suggested that the city's six million inhabitants were used as guinea pigs to test the effects of radioactivity and could be eligible for compensation. Soon after this scientists calculated that the highest dose of radiation anyone would have been exposed to, some 15 miles (24km) from the test site, was a modest 5.7 millirads. In Los Angeles, some 200 miles (320km) distant, the dose would have been absolutely negligible causing to no measurable health effects. Today this kind of experiment would be considered unacceptable and, although the Kiwi-TNT test raised few public concerns at the time, it would be an uphill struggle to introduce nuclear rocket propulsion in the present era, even if fissile material was only being transported into orbit for interplanetary use.



Bottom left: **The first US nuclear test rig was known as Kiwi-A and trials began in 1959. The Los Alamos Scientific Laboratory developed the reactor for the Atomic Energy Commission.** NASA



Bottom right: **In 1965 a Kiwi nuclear reactor was deliberately blown up to test a worst-case power transient event during launch. Considerable radiation was released and it is hard to imagine a repeat of this experiment taking place today.** NASA



However, putting these issues aside, manned interplanetary exploration had already been dealt a major blow during 1962 when the US Mariner 2 probe showed that Venus, once thought to be the Earth's 'twin', was suffering from a runaway greenhouse effect and conditions on its grim rocky surface were totally unsuitable for man or machine! Clearly NASA, the US military and their Soviet counterparts were never going there!

Three years later NASA's Mariner 4 spacecraft returned the first detailed images of the Martian surface. Again scientists around the world were shocked and disappointed to discover that the planet's cratered surface looked more like the Moon. The carbon dioxide atmosphere was much thinner than expected and it was depressingly obvious that Mars was a cold, bleak, barren world. Although somewhat dented, the American public's enthusiasm for space exploration remained high and there was the very real possibility that Russia would reach the Moon first and go on to Mars, so there were still some flags to plant and regions to claim! Because of this, proposals for a high profile US manned Mars flight continued to evolve within NASA and, despite stretching science and technology to the limit, a mission was being planned which would start during November 1981.

Nuclear propulsion was considered essential for a Mars mission and work on Project Rover (now often called by the original name NERVA) continued at Jackass Flats with the KIWI reactor series being superseded by Phoebus and NRX designs that finally exceeded the initial Project Rover specification. By the end of December 1967 an NRX reactor rated at 1,100 Megawatts had been run up to full power and operated continuously for sixty minutes and then shut down. Ramp up time to full power was regarded as good, taking about sixty seconds, with a further sixty seconds required to reach shutdown. This gave way to the XE 1100 design which was the first engine to be tested in a downward position. XE was run twenty-eight times during 1968 and it was felt that this technology was developing well and would soon be ready for use in space, if the funding was maintained. Various proposals for a NERVA-powered Mars spacecraft were put forward by all the major US aerospace contractors and each design was based on a multi-stage vehicle assembled in LEO.

The 1969 plan developed by NASA's Space Task Group envisaged a 640 day round trip for two ships starting in November 1981. Both vehicles would reach the Red Planet by August 1982 and each would carry a landing craft which resembled a scaled up Apollo capsule. Three crew members from each team would descend to the surface where they would remain for a maximum period of about thirty days. During the return stage of the journey a close flypast of Venus was

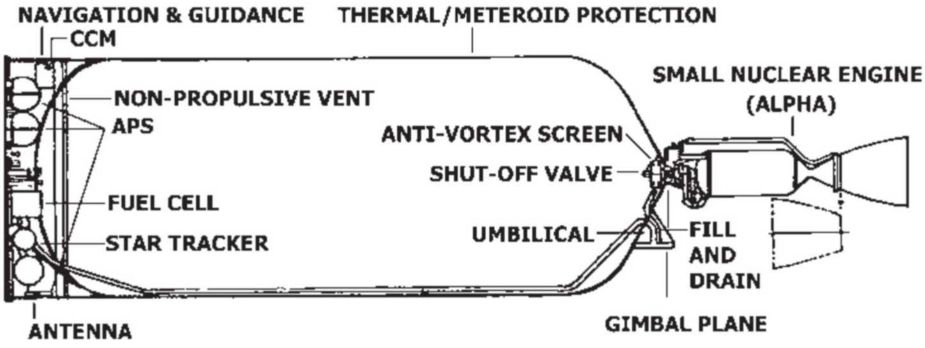
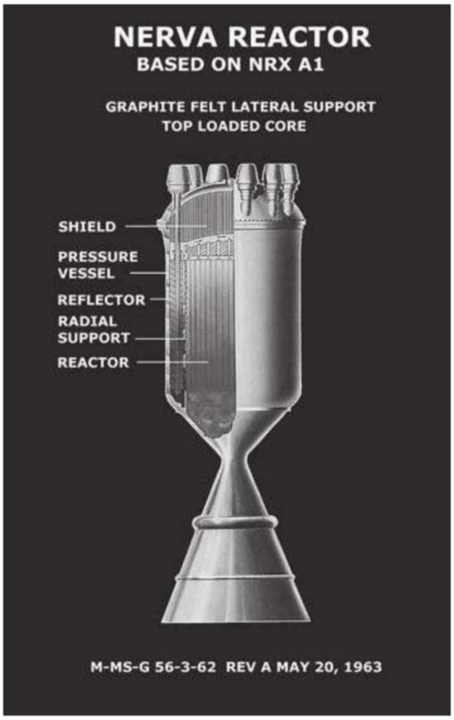


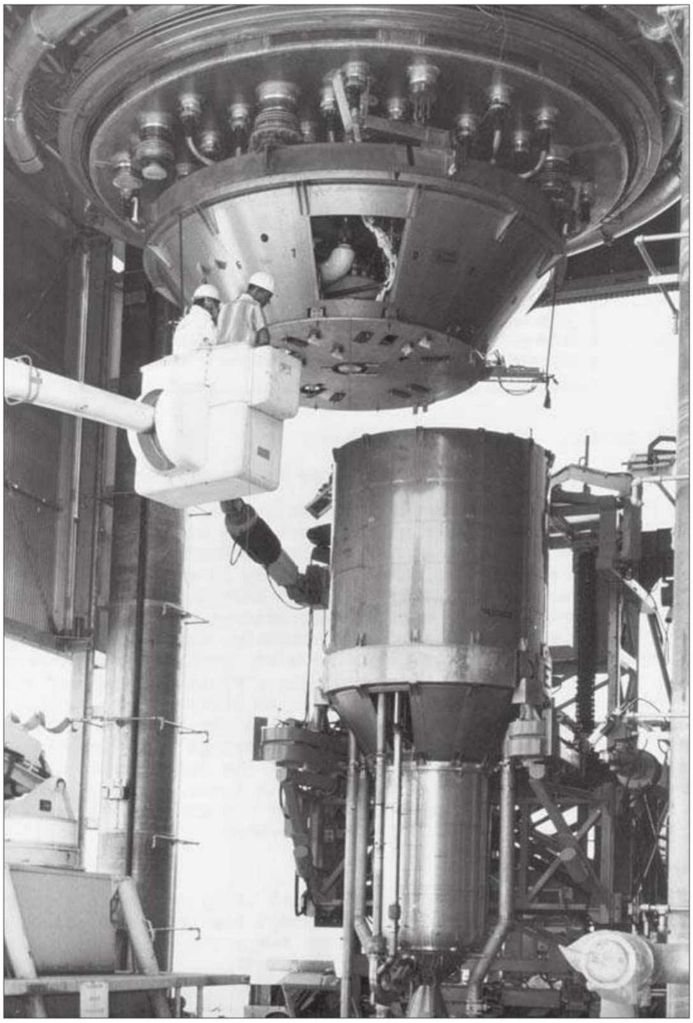
Fig. 10 McDonnell Douglas reusable nuclear stage concept.

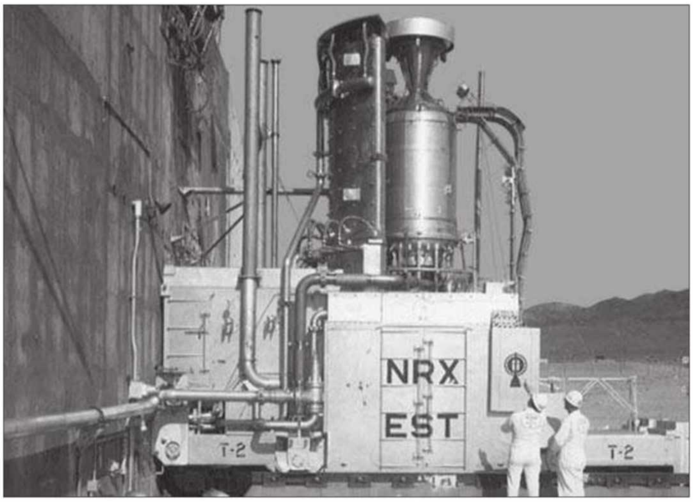
Top left: **When NASA's space probe Mariner 4 returned the first close-up images of the Martian surface, scientists were shocked to discover the planet was far less hospitable than previously envisaged. Information relayed by this spacecraft had a considerable effect on shaping US and Soviet space ambitions beyond the Moon, with manned exploration of the Red Planet quickly giving way to long-term studies using automated vehicles.** NASA

Top right: **Two possible uses for a nuclear shuttle stage.** NASA

Right: **McDonnell Douglas drawing of a complete re-usable nuclear rocket stage.** NASA


NERVA REACTOR
BASED ON NRX A1
GRAPHITE FELT LATERAL SUPPORT
TOP LOADED CORE
SHIELD
PRESSURE VESSEL
REFLECTOR
RADIAL SUPPORT
REACTOR
M-MS-G 56-3-62 REV A MAY 20, 1963




NRX
EST
T-2
T-2

Opposite page, clockwise from top left:

A plume of hot exhaust gas shoots up from the Phoebus 1A experimental nuclear engine on 24th February 1967. NASA

The principles of the NERVA NRX A1 nuclear rocket engine. NASA

The NRX nuclear rocket engine is prepared for testing at Jackass Flats, Nevada in early 1966. NASA

The XE nuclear engine assembled in cold flow configuration is transported to Engine Test Stand No 1 at the Nuclear Rocket Development Station, Jackass Flats, on 1st December 1967. A cold flow experiment means that the engine function is tested without any fissionable material present. The large unit on the right is an aluminium closure used to create an airtight compartment around the engine and simulate a space environment. NASA

The XE nuclear rocket engine being installed in Test Stand No 1 for a series of cold flow tests. NASA

This page:

Left: **Artwork depicting a manned Mars mission, based on a 1968 study undertaken by Boeing for NASA.** NASA

Right: **An advanced nuclear shuttle vehicle designed to act as a ferry between the Earth and Moon.** NASA

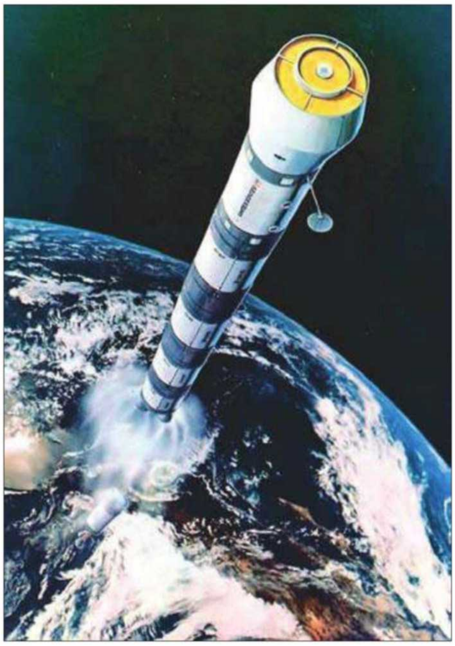
planned and several automated probes would be deployed. The Mars ships would finally arrive back in Earth orbit during August 1983.

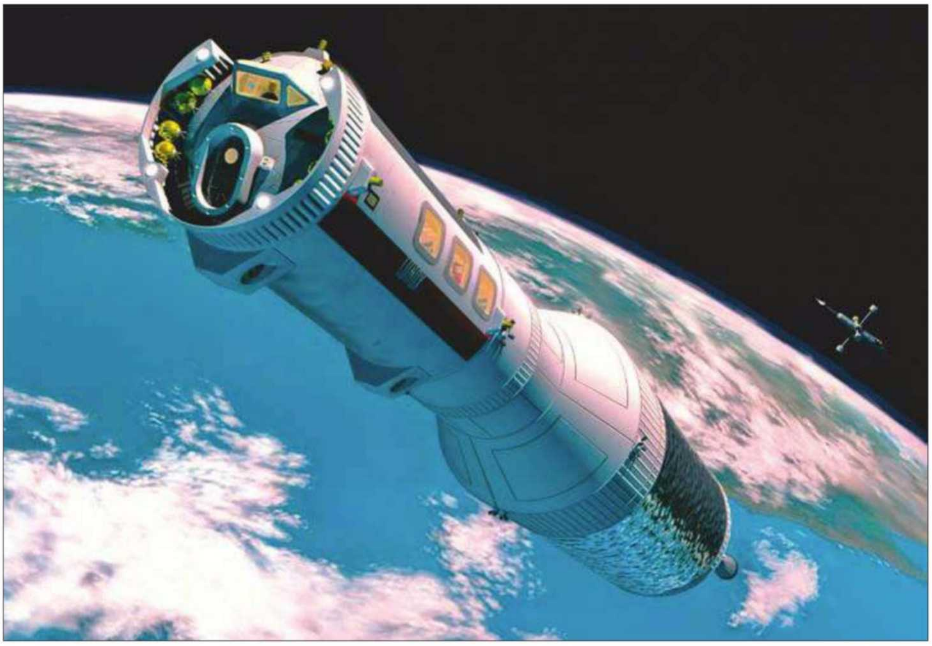
In addition to the development of NERVA rockets for the Mars mission, a series of studies was started in 1971 to provide a small nuclear engine to power the proposed Space Shuttle. The system was based on a reactor design called PEEWEE. This unit weighed 5,632 lb (2,555kg) and used composite Uranium-Zirconium Carbide fuel elements with hydrogen as the propellant. The reactor achieved very high core power density levels and exceeded its original specification. Two further reactors called Furnace 1 and 2 were built during the Rover/NERVA programme which explored various fuel element configurations, but in 1972 the manned Mars project was cancelled along with the remaining Apollo Moon missions. The bottom had unexpectedly fallen out of space exploration and, although the US was almost ready to start building operational nuclear rocket engines, the $1.4 billion programme was scrapped.

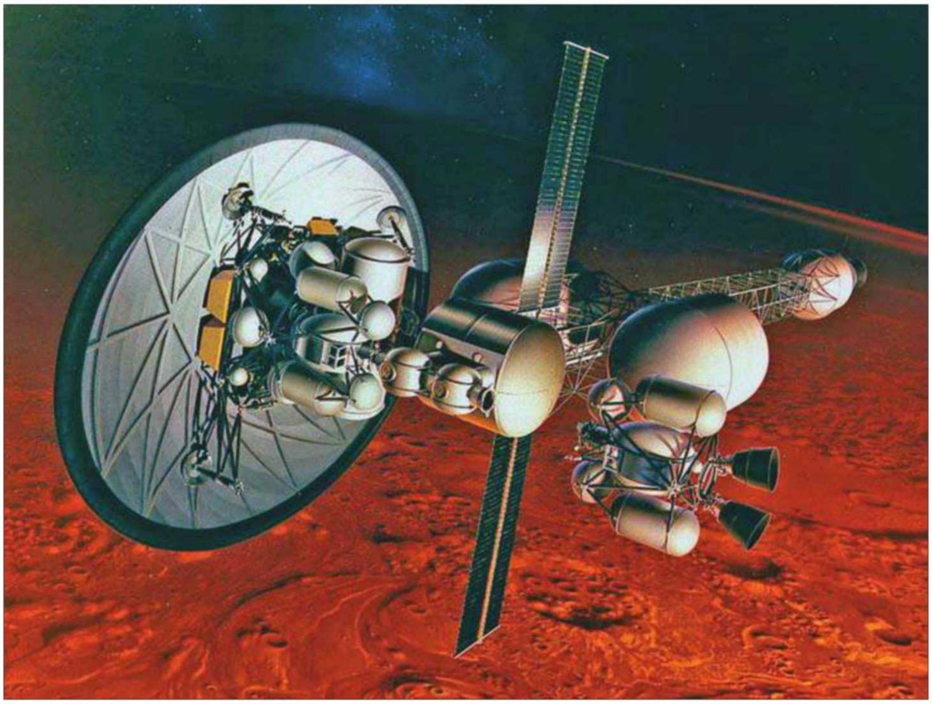
This seemed to be the end for America's plans to use nuclear space propulsion, but NERVA was secretly revived in 1983 as part of the SDI programme. Under the direct control of Lt-General James Abrahamson, the new nuclear thermal engine programme was assigned the name Project Timberwind in 1987 and it was proposed as an expendable single-use engine for an unmanned interceptor vehicle mounted above an MX Peacekeeper solid fuel stage. Anticipated velocities of 7 miles/sec (11km/sec) were considered realistic and the payload would be an Excalibur nuclear-pumped X-Ray laser weapon. The second Timberwind application was to lift heavy payloads into orbit such as laser and electromagnetic railgun platforms. The USAF's Phillips Laboratory at Kirkland AFB took responsibility for managing Timberwind and many large defence contractors, such as Raytheon, General Dynamics and Babcock & Wilcox's Nuclear Power division, were involved plus research facilities that included the Sandia National Laboratory and Brookhaven National Laboratory.

Not surprisingly the site for eventual static ground testing was Jackass Flats, but there were further suggestions for conducting the secret launch of a Timberwind upper stage mounted on a Titan III from Vandenberg AFB in California. This would have involved placing the test vehicle on a trajectory across the South Pacific Ocean with a nuclear burn above Antarctica, although there were concerns that any accident might result in debris impact around the New Zealand area. The Particle Bed Reactor (PBR) developed for Timberwind had already been considered as a multi-megawatt burst-mode electrical power delivery system for space-based directed-energy weapons. Inside this type of reactor the uranium fuel-element particles are contained within porous cylindrical screens referred to as frits. The outer frits were made from a newly developed Inconel (nickel base) alloy and the inner high-temperature frits from a mixture of tungsten and rhenium. Hydrogen flows inwards and reaches an average exhaust temperature of 4,038°F (2,226°C), but one major problem with this design (which scientists recognised early on) was 'frit clogging' from particle debris. Predictions suggested that a reactor failure due to this difficulty would occur at 3 in every 1,000 operational cycles.

Other problems inherited from NERVA included excess vibration and component disintegration, although this was greatly reduced by the use of carbon-carbon parts







The possible appearance of a nuclear powered manned Mars ship in orbit above the Red Planet. Note the substantial aerobraking shield. NASA

like the specially coated anti-erosion turbopump blades. Of course in the case of an expendable booster for an unmanned vehicle this is less of an issue. Two big improvements over NERVA were the employment of more efficient slush/gelled hydrogen for fuel and lithium hydride as a moderator, which made the construction of a much smaller reactor possible. This meant that the Timberwind PBR engines were about half the size and weight of the most advanced NERVA designs, while providing much higher performance and a significantly smaller shielding requirement. Their outstanding 'ramp-up' throttle characteristics made it possible to reach full power from the minimum level in ten seconds or better, which was a huge improvement over the NERVA engines built in the 1960s. The compact lightweight design would allow the use of several engines for any given application and improve the level of redundancy in the event of a component failure.

NASA was aware of the Timberwind programme and was allowed to take an informal interest, but it seems that the transfer of technical information to the agency was somewhat restricted. This was undoubtedly frustrating as calculations had showed that significant performance and reliability improvements would allow NASA to trim something like sixty days off the proposed NERVA-powered round trip to Mars. By 1990 there were three engine designs in development which were simply called Timberwind 45, 75 and 250. These numbers related directly to the engine performance. It is probable that at least one proof-of-concept Timberwind reactor was built and tested in a closed-cycle environment at the Nevada Test Site, but many details of the Timberwind programme remain classified. No open-air static tests took place because the release of radioactive materials into the atmosphere would have been apparent to everyone having an interest in these matters.

Despite all the improvements this system promised its development costs remained very high, and when the Soviet Union collapsed SDI-related funding was seriously curtailed. In January 1992 the Timberwind project was officially terminated, although work on nuclear thermal engines, and particularly PBR designs, may well be continuing as part of one or more undisclosed programmes. Until something better comes along, nuclear thermal or nuclear-electric propulsion remain the most effective choice for any manned mission beyond the Moon, such as to Mars, Mercury or one of the larger asteroids. Transit time for deep space missions must be as short as possible to avoid severe psychological problems for the crew, and the even greater dangers posed by prolonged exposure to solar and cosmic radiation.

Soviet Nuclear Rockets

Like their American rivals Soviet scientists embarked on a long and expensive programme of nuclear rocket engine research and development that began in the late 1950s. Mikhail Klavdiyevich Tikhonravov (1900-1974) was one of Korolev's leading research scientists and he conducted the first complete study for a Soviet Mars mission in 1956. Tikhonravov estimated that a chemically-fuelled vehicle would need to be at least 1,600 tons (1,452 tonnes) in mass to make the journey. Placing the components in orbit would take a minimum of twenty-four launches using the proposed N-1 booster and this would be accompanied by intensive assembly work in orbit. Such an undertaking was clearly unacceptable and the Russians wasted no time deciding that atomic energy was essential for any manned mission to Mars or Venus. By 1960 there were three separate designs for nuclear thermal engines under consideration, with the leading proposal being handled by Korolev's OKB-1.

Manned deep-space missions were the more openly discussed uses for this technology, but behind the scenes the Soviet Ministry of Defence sought a high performance engine for use with an ICBM carrying a large nuclear warhead that could be delivered to any point on the globe. Korolev's OKB received approval to study a single-stage nuclear-powered ICBM known as YaRD on 30th June 1958 and a detailed proposal had been completed by the end of 1959. The missile's provisional specification included a maximum length of about 82ft (25m), a diameter of 10ft 10in (3.3m) and a mass of 186,000 lb (84,368kg). The nuclear engine used ammonia as a propellant and had an anticipated lift-off thrust of 282,135 lb (1,255kN).

There were two alternative engines for YaRD under development by Glushko's OKB-456 and Bondaryuk's OKB-670. The Glushko was similar in performance to the OKB-1 design and also utilised ammonia as a propellant, while the more powerful Bondaryuk engine operated with a mixture of ammonia and alcohol to provide an anticipated lift-off thrust of 342,833 lb (1,525kN). It was decided that the first YaRD test flight (using the OKB-1 engine) would terminate in a specially constructed reservoir at the impact site. Nevertheless, increasing concerns about safety and the dire consequences of an accident led to the missile's cancellation in late 1960. However, OKB-1 continued to develop its nuclear thermal engine which was similar to the American Kiwi design apart from using ammonia as a propellant instead of hydrogen. The alternative OKB-456 and OKB-670 engines were now being considered for upper-stage rocket applications and a switch was made to liquid hydrogen after it was determined to be the preferable propellant, despite ammonia having some technical advantages.

In 1961 the Scientific-Technical Committee agreed that an engine with a 30 to 40 ton (267 to 356kN) thrust would satisfy all forthcoming requirements, but Korolev was allowed to set up another facility to develop a much more powerful design called the RD-600. This reactor would undergo many revisions and RD-600 remained under steady development from 1962 to 1970. However, in 1962 all new engineering development was passed to OKB-154 run by Semyon Kosberg (1903-1965). This design bureau at Voronezh had considerable experience with liquid fuel rocket engines and it also teamed up with the Kurchatov Institute and Keldysh Scientific Centre. Nuclear engine development proceeded at a fairly leisurely pace during the remainder of the 1960s with the Government giving full priority to its secret Moon project. By the end of this period Kosberg had built several experimental nuclear rocket engines but the history of this work is not well documented.

In 1971 the programme was passed to NPO Luch (the Scientific Production Association) which began ground tests at Semipalatinsk-21. This led to a revised engine called Baikai-1 being built which was run on at least thirty occasions during a lengthy eighteen year period, without a single failure. It has also been reported that during the early 1970s two other advanced nuclear thermal engines were designed and assembled by NPO Luch. These were the compact RD-0410 'Minimum' engine offering 3.5 tons (31kN) of thrust and the much bigger RD-0411 engine with a thrust of 70 tons (622kN). Both are believed to have been tested at Semipalatinsk-21 but this has not been confirmed.

With the Americans about to land on the Moon the Soviet leadership turned its attention towards the possibility of a manned Mars mission. Three OKBs headed by Yangel, Mishkin and Chelomei were told to begin work on the design of a nuclear-powered interplanetary spacecraft and a landing vehicle, all under the cover name Project Aelita (Aelita or Queen of Mars was a 1924 Soviet sci-fi movie). The initial requirement was to undertake a 630-day round trip and allow half the crew to spend seven days on the Martian surface. By the start of the 1970s Chelomei was the only designer still working on Project Aelita. He proposed the construction of a huge nuclear-thermal-powered space vehicle called the MK-700 which would have a length of 459ft (140m), a diameter of 41ft (12.5m) and a mass of 1,543 tons (1,400 tonnes). The spacecraft would be assembled in orbit and would require a massive new launch vehicle called UP-700M. The three-stage liquid-fuelled UR-700M had a proposed length of about 574ft (175m), a core diameter of 101ft (31m) and a massive launch weight of 17,637 tons (16,000 tonnes). Designed to support the Mars spacecraft, UR-700M would have the ability to place a 750 ton (680 tonne) payload into LEO.

It was finally decided that MK-700 would carry a crew of two and Chelomei's engineers managed to reduce the mass to around 1,102 tons (1,000 tonnes). Formal plans were presented to the State in 1972 and a panel of academics was assembled to review the MK-700 spacecraft and UR-700M launch vehicle. The panel quickly determined that both projects were over-ambitious and would require tens of billions of roubles to develop. Funding at this level was simply not realistic and the panel recommended that a manned Mars mission should be placed on indefinite hold. Despite this work on nuclear-thermal (and nuclear powered ion) engines continued at a modest level, and by the early 1990s Russian scientists claimed to have made significant progress with the technology, appearing more confident about its use than their American counterparts. Perhaps this came about because the Russians aimed for maximum reliability as opposed to undertaking cutting edge engineering that tried to extract every last drop of power from very complex designs. Needless to say the various Russian nuclear space propulsion programmes were abandoned when the country's economy collapsed and there seems little likelihood of a revival in the immediate future.

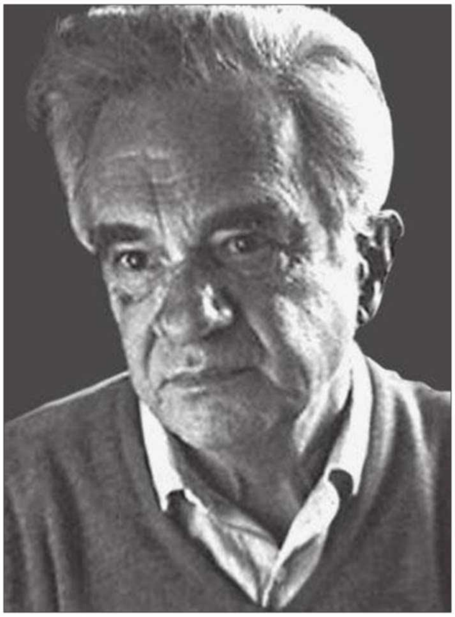
Riding the Pulse

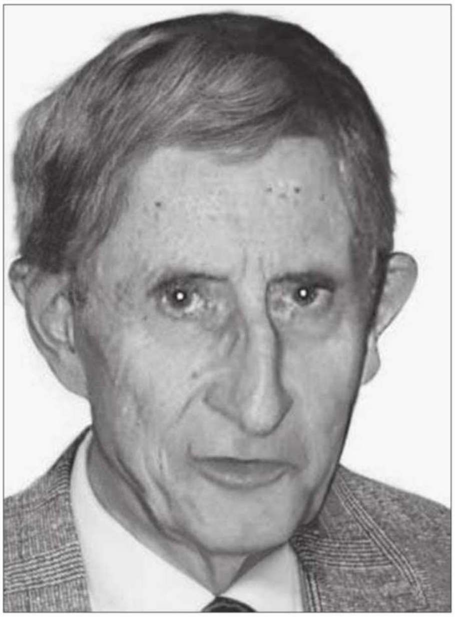
During the mid-1950s American scientists conceived a fairly radical 'brute force' approach to the use of nuclear energy for spacecraft propulsion. This was based on the seemingly crazy idea of detonating small nuclear explosions behind a space vehicle to generate forward motion. The initial proposals came from Stanislaw Ulam and Cornelius Everett who both worked at the Los Alamos Scientific Laboratory. However, the original concept for a reaction-powered spaceship using dynamite charges dates back to 1890 and was dreamt up by a German rocket enthusiast called Hermann Ganswindt (1856-1934).

Various ideas produced by Ulam and Everett soon led to a classified space propulsion study undertaken by the Glenn L Martin Company, which examined the idea of detonating small 0.1 kiloton nuclear bombs within a 130ft (39.6m) diameter combustion chamber. The bombs would have been injected into the chamber at a rate of one per second, with water being added as a propellant. The intended application of this huge combustion chamber is unclear but Martin engineers considered it to be 'dirty technology'. They recommended launching vehicles using this type of propulsion system into a 150-mile (241km) orbit with chemical boosters before attempting to use it. At about the same time the Lawrence Livermore Laboratory developed a similar but much smaller nuclear pulse combustion chamber called Helios. But when Ulam and Everett reviewed these studies they realised that a combustion chamber was rather unsatisfactory and it could probably be dispensed with altogether. If the force from an external detonation was directed against a large pusher plate, it would be just as effective.

Their colleague Dr Theodore (Ted) Taylor (1925-2004) continued to develop this idea and in 1957 he joined General Atomics, which was being run by former Los Alamos scientist Frederick de Hoffman. As a division of General Dynamics the company's main business was developing nuclear reactors, but it seems that Taylor was given a free hand and allowed to fully investigate the possibilities of nuclear pulse engine technology. De Hoffman was clearly impressed with the potential of nuclear pulse for space applications and

In 1890 a German law student called Hermann Ganswindt (1856-1934) conceived the idea of propelling a space vehicle by means of dynamite charges. Bill Rose





Far left: **Ted Taylor joined General Atomics in the late 1950s to develop the nuclear pulse engine concept.** US Department of Defense

Left: **The brilliant physicist Professor Freeman Dyson who worked with Ted Taylor on the Orion nuclear spacecraft project.** Bill Rose

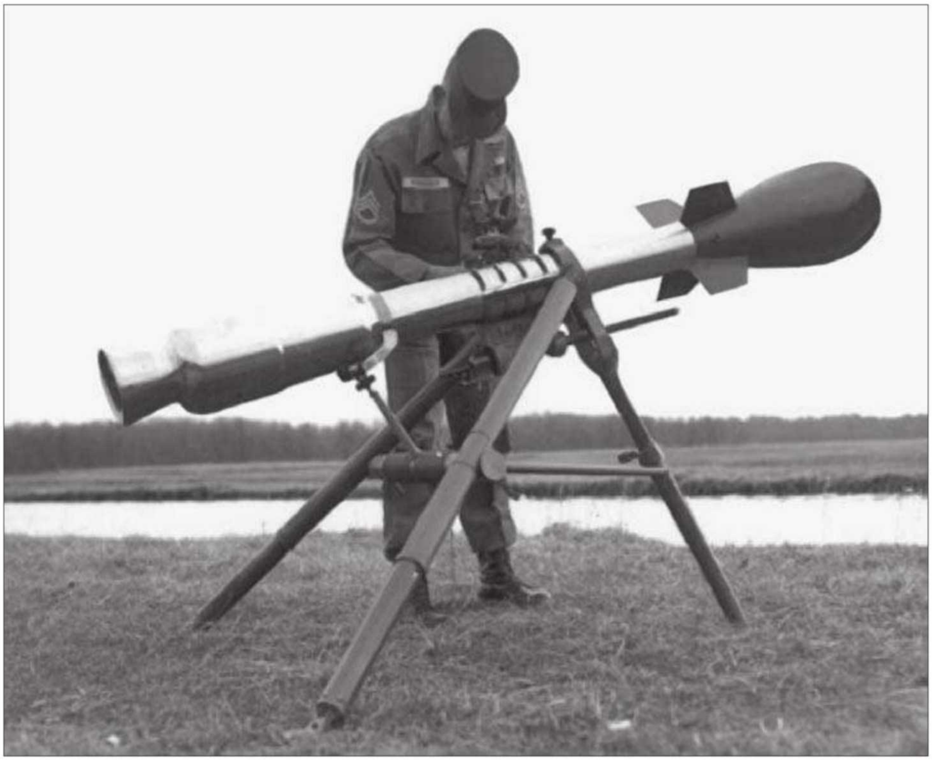
Bottom left: **The Davy Crockett missile fitted with an extremely compact variable-yield nuclear warhead designed by Ted Taylor. This weapon set the standard for miniaturisation and made the idea of nuclear pulse propulsion a theoretical possibility.** US Army

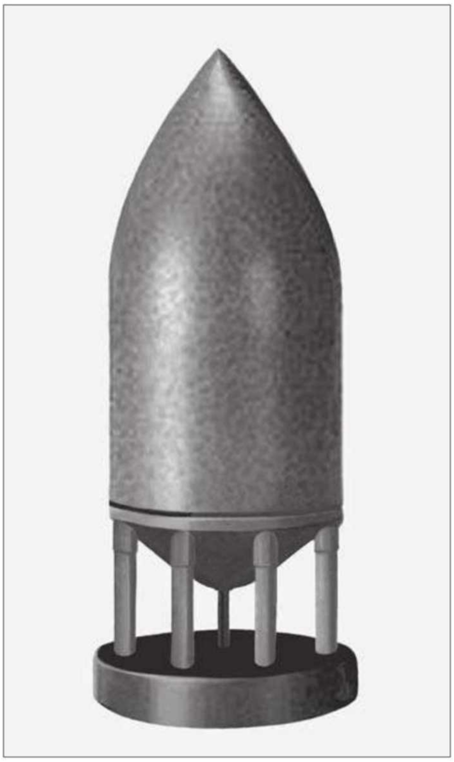
Bottom right: **The first designs for the Orion nuclear-powered spacecraft took the form of a massive artillery shell with a rear-mounted pusher plate attached by giant hydraulic shock absorbers. Weighing thousands of tons, the vehicle would be supported by eight towers above the launch pad in Nevada.** Bill Rose

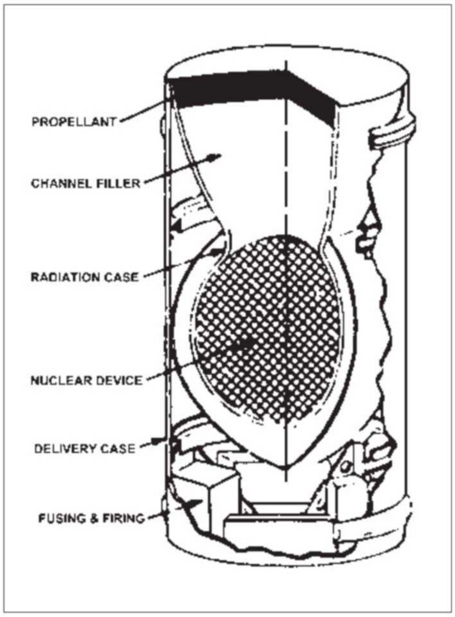
managed to recruit the highly respected physicist Freeman Dyson to work alongside Taylor on the project.

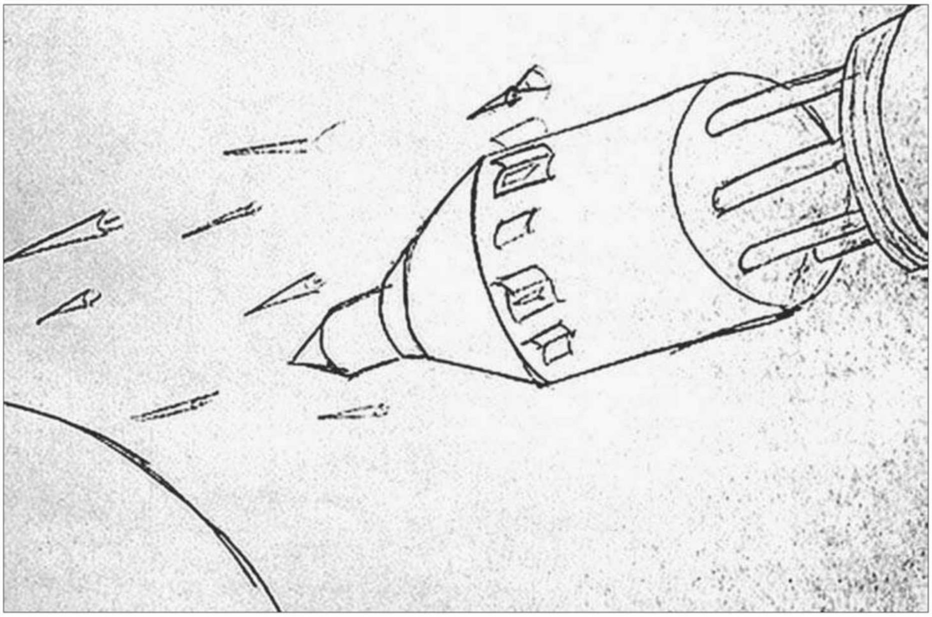
At that time Professor Dyson was teaching at the Institute for Advanced Studies at Princeton, New Jersey, but the concept had caught his imagination and he arranged to take a one-year sabbatical from his post. Ted Taylor had been responsible for designing the miniature low-yield nuclear W54/Mk-54 series of warheads for the Davy Crockett rocket, the Special Atomic Demolition Munition (SADM), the Genie air-to-air missile (AAM) and the AIM-26A Falcon AAM. In the late 1950s a man-portable nuclear weapon with a variable yield up to about 1 kiloton was considered cutting edge and the development of this technology would play a key role in the design of a nuclear pulse engine.

During 1958 General Atomic secured a one million dollar contract from the USAF to study nuclear pulse propulsion for space applications and the research was immediately classified as top secret and given the project codename Orion. From the outset it was clear that an Orion spacecraft would be substantial in size. Small nuclear charges would be ejected from the rear of the vehicle and they would explode about 200ft (61m) behind a massive plate to generate forward thrust. The nuclear charge would be accompanied by a quantity of fluid to generate plasma which would momentarily reach a temperature of 144,000°F (80,000°C), although the effects of the explosion would be so brief they would cause no damage to the spacecraft.









As the design work on the Orion vehicle began to evolve, it took on the appearance of a massive artillery shell with the pusher plate at the rear attached by several huge shock absorbers. If they could get this extraordinary contraption to work, it would produce an unprecedented technical leap forward with the potential to open up the Solar System for manned exploration, while providing the military with a capability that had only been previously visualised by sci-fi writers. In military terms it might be possible to orbit spacecraft the size of naval warships that carried hundreds of nuclear missiles, or perhaps just one massive doomsday weapon capable of devastating half a continent.

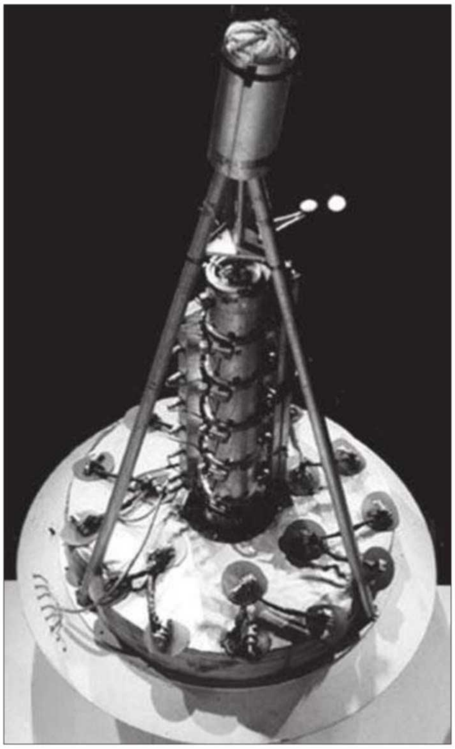
Alternatively, an Orion spacecraft might be used in the strategic defence role with the ability to unleash a cloud of depleted uranium rods that would destroy a full-scale Soviet missile launch. These huge spacecraft would have 'Star Trek'-style individual living quarters, artificially induced gravity and hangar decks. They would be equipped with at least five hundred rocket-launched Minuteman warheads for use against Earth or space targets, although there was the vague suggestion that this massive firepower might be employed to divert a dangerous asteroid if the need ever arose. A further development called the 'Deep Space Force' would comprise about twenty Orion-class spacecraft placed in lunar or high Earth orbit beyond the easy reach of hostile forces. Each Orion would be manned by a USAF crew of about thirty personnel undertaking a six-month tour of duty. In addition to being used as a weapon system, Orion would make it possible to deliver in just one launch everything needed to establish a substantial military outpost on the Moon. It was potentially rather risky, but the idea generated considerable interest amongst members of the USAF who were studying the possibility of future bases on the Moon.

As the Orion project gathered momentum engineers at San Diego built several small proof-of-concept models that worked with conventional explosives. Given the names Put-Put and Hot Rod, the first vehicles were destroyed during testing at Point Loma, California (which was a former Atlas missile test site). Some design problems needed to be addressed but a launch during November 1959 finally demonstrated that five C-4 explosive charges could be used to propel one of these small vehicles to an altitude of 300ft (91m) in a stable manner, before it was returned to the ground by parachute. It was also realised that the pusher plate would need to be thickest at the centre and taper towards the edge. Steel or aluminium was

Top left: **Schematic of the cylinder containing the nuclear charge and propellant for ejection behind an Orion spacecraft.** USAF

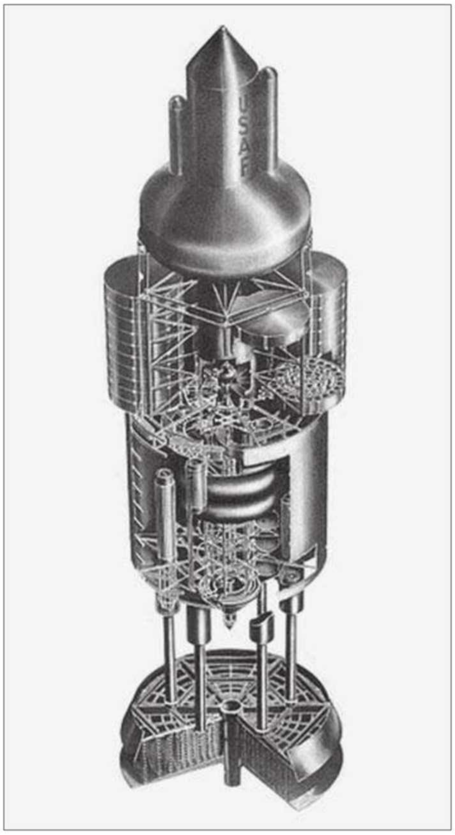
Top right: **An original sketch (probably made by Freeman Dyson) showing an Orion launching an attack from orbit. This was found within a declassified General Atomic document and it is described as 'Strategic Weapon Delivery'.** USAF

Right: **Two spacecraft belonging to the USAF's Deep Space Fleet in orbit above the Moon. Vehicles of this size and capability remain unlikely in the foreseeable future.** Bill Rose, based on original USAF artwork



One of the original Orion project proof-of-concept vehicles, designed to be propelled by small C4 explosive charges. USAF

An evolved design of the Orion nuclear spacecraft showing the vehicle's internal structure. USAF



considered adequate for plate material, although there were ongoing concerns about severe forward acceleration. With trials of the models progressing well, Taylor and Dyson began to consider the construction of a full-sized Orion spacecraft, which the USAF suggested could be launched from Jackass Flats, Nevada. This massive vehicle would be sixteen stories high and would sit on a hydraulically-dampened pusher plate measuring 135ft (41m) in diameter.

Construction methods had more in common with a submarine than a spacecraft and General Dynamic's Electric Boat Division was commissioned to undertake the initial engineering studies. Eight towers were considered necessary to support the 4,000 ton (3,629 tonne) spaceship above the launch pad and lift-off would be achieved with an initial 0.1 kiloton detonation, followed by further explosions spaced at one-second intervals. As altitude increased the detonation rate would slow but the yield would increase until 20 kiloton explosions were taking place. Perhaps the biggest challenge facing the engineers was devising a suitable ejection mechanism for the nuclear charges and this went through countless design revisions until a suitable method was found that allowed rapid and reliable firing.

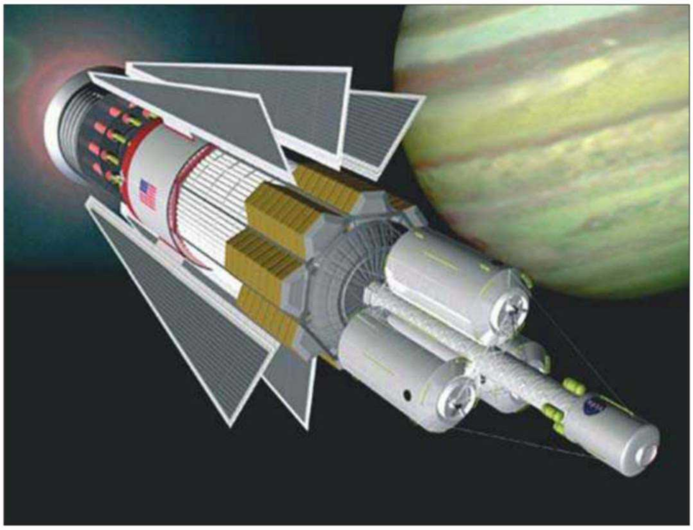
The possibility of high acoustic levels within the Orion vehicle was also recognised as a serious issue but suitable insulation was expected to resolve this problem. Then there was the issue of nuclear fallout to overcome and projections showed there was a likelihood of several deaths caused by radioactive pollution from each launch. However the biggest issue, which scientists completely overlooked at that time, was the Electromagnetic Pulse (EMP) generated by the propulsion system. This would have caused widespread damage to electronic equipment. Once in Earth orbit (or above another planetary body), flights to and from Orion would be made by smaller chemically-fuelled spaceplanes or vacuum landers and the Orion vehicle would never return to Earth.

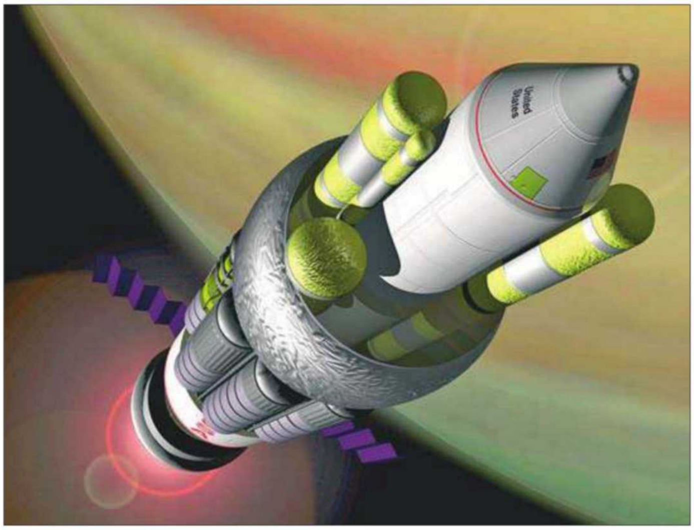
Even at an early stage Taylor and Dyson considered a one million ton spaceship feasible and discussed the idea of eventually being able to cross the entire Solar System in one month at speeds in excess of 6,000 miles/sec (10,000km/sec). Today Orion sounds like a ridiculous sci-fi adventure put forward by a group of mad scientists, but the basic idea was probably workable and Project Orion had the ability to advance America's space programme by perhaps a century and divert the course of history onto an entirely new track. The development cost suggested by Taylor and Dyson was a modest $100 million per year over a twelve-year period, but the USAF had begun to have second thoughts about this project and NASA was deeply unhappy about the use of dirty technology within the Earth's atmosphere. As a consequence Kennedy's Defence Secretary Robert McNamara decided to cut back funding for Project Orion in 1961. Soon after this Taylor and Dyson undertook the first of several meetings with senior NASA officials at the Marshall Space Flight Center. They tried to convince them that a manned Mars mission could be undertaken by 1965 using an Orion spacecraft, and this might be followed by a manned flight to Saturn's moon Titan in 1970.

With the enthusiastic support of Wernher von Braun they suggested that a proof-of-concept vehicle could be assembled in LEO using two or possibly three Saturn V launches, and an Orion spacecraft could easily fly to the Moon and back to demonstrate the propulsion technology. While these attempts to attract interest from NASA continued, a substantial mock-up of a military Orion was built for the USAF by an unnamed San Diego subcontractor at an estimated cost of $75,000. This was shown to President Kennedy at Vandenberg AFB in early 1962.

According to George Dyson in his book *Project Orion*, Kennedy was absolutely appalled by what was going on and said he had no use for such a system. This was bad news for the project and Taylor switched to promoting Orion for space exploration with a re-packaged version of the spacecraft. He submitted proposals to NASA for a relatively small 200,000 lb (90,000kg) Orion prototype that could be launched with a conventional booster and tested in space. It would be equipped with a 33ft (10m) diameter pusher plate that was limited by the diameter of the Saturn V launch rocket. Although the capability of this spacecraft would be limited in comparison to the original design, it would still outperform any nuclear thermal-powered spacecraft by a wide margin. Taylor and Dyson went on to suggest that this Orion 'Lite' could easily transport eight astronauts and 100 tons (90.7 tonnes) of equipment to Mars in an astonishing round trip time of about 125 days during a suitable opposition. But NASA still regarded Orion as a dangerous unexplored concept and the agency was committed to the Apollo Moon project, while reluctantly continuing to develop NERVA for a possible Mars mission.

In August 1963 the USA, UK and Soviet Union signed the nuclear test ban treaty and NASA saw this as an endorsement of their decision to reject Project Orion. The follow-





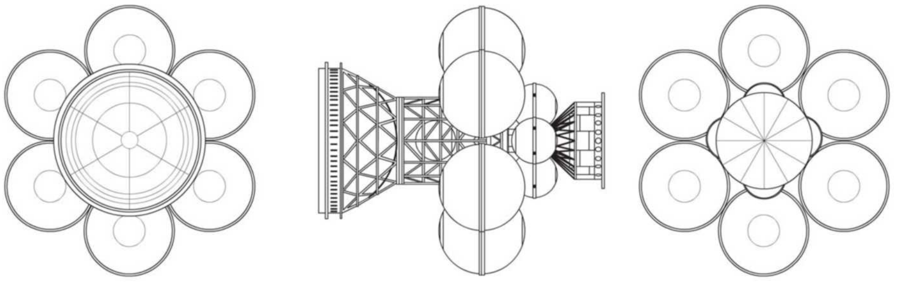
ing year USAF funding came to an end and the Orion project was over. In total the programme had cost about $10 million, which was roughly the same as Stanley Kubrick spent on the movie *2001 – A Space Odyssey* made a few years later. It's worth noting that Arthur C Clarke (who co-wrote the '2001' screenplay) considered using a fission pulse engine for the film's spacecraft after reading a brief outline of Orion which had been declassified in 1964. But by the time he discussed this idea with Kubrick the production was too far advanced for it to be included.

By the late 1960s Freeman Dyson had privately developed the Project Orion study to the limits of prevailing technology and began to consider its possible use for a starship able to reach the nearest systems. This idea indirectly formed the basis of The British Interplanetary Society's Daedalus Project of 1973 to 1977, which was headed by Alan Bond who later invented the air-breathing engine proposed for HOTOL. Under his direction the feasibility of building an unmanned interstellar probe was carefully studied by a small group of specialists. Daedalus would utilise technological developments anticipated by the early 21st Century and would be capable of reaching Barnard's Star in less than the average human lifespan. Barnard's Star (a dim M4 red dwarf) was chosen as their target because it is relatively close to us in interstellar terms (5.96 light years) and was thought to have at least one planet.

Today's choice for an interstellar mission would almost certainly be Alpha Centauri, which is a triple star system and our closest neighbour at a distance of about 4.3 light years. Many astronomers now believe that Centauri A (G2 V) and Centauri B (K1 V) could have planetary systems and perhaps one Earth-like world harbouring some form of life. The third component of this system is Proxima Centauri and, although it is slightly closer to us, this star is another faint red dwarf and therefore not so interesting.

The Daedalus spacecraft was a huge 54,000 ton (49,000 tonne) two-stage design evolved from Orion and 50,000 tons (45,360 tonnes) of this mass would be taken up by fuel. Propulsion took the form of a pulsed fusion engine using pellets made from helium 3 and deuterium. Each pellet would be ignited by electron or laser beams after ejection at a rate of 250Hz. The plasma from the explosion would be contained and shaped by magnetic fields, making more efficient use of the energy than a simple pusher plate. Although controlled fusion remains the goal of many scientists, efforts to develop this technology have proved painfully slow. But Bill Emrich working at NASA's Marshall Space Flight Center has already undertaken simple experiments with argon plasma and he believes that a Daedalus fusion drive is feasible. Emrich has suggested that if stable, break-even fusion is achieved in the near future, a 320ft (100m) long propulsion unit could be built, providing at least 300 times the performance of the most powerful chemical rocket.

In the case of a Daedalus starship launched from an orbit above one of Jupiter's moons, the first stage would operate for two years and propel the starship to 7.1% of the speed of light. Then stage two would burn for a further 1.8 years taking Daedalus to 15% of the speed of light allowing the vehicle to reach Barnard's Star within fifty years. As there would be no way of slowing the starship on arrival at its destination, eighteen super intelligent probes would be despatched to investigate the star system. Whether such an expensive and technically challenging vehicle will ever be built remains unknown, but I rather doubt that such a project is possible within the lifetime of anyone reading this book. Having said that, I could be wrong!



Top left: **Fairly recent NASA concept for a manned deep-space vehicle using a pulse engine based on the original Orion concept.** NASA

Top right: **One of several more recent NASA concepts for a development of the nuclear pulse drive.** NASA

Right: **The British Interplanetary Society's Daedalus Starship designed in the 1970s. This represents the ultimate development of the Orion nuclear pulse drive.** Chris Gibson

Chapter Seven

Destination Moon

In the immediate post-war years the Moon began to generate serious military interest because ideas that belonged to the realm of science fiction started to seem like near-future possibilities. The 1950 film *Destination Moon* produced by George Pal was based on a screenplay co-scripted by the influential science fiction writer Robert Heinlein, and it reflected the aspirations of many scientists involved with rocketry. The following year G V E Thompson produced one of the first serious studies for a base on the Moon, which appeared in the BIS's Journal for March 1951. He suggested that the facility might be used as a 'coaling station' for nuclear-powered rockets travelling to Mars and Venus, with propellant being prepared on the Moon rather than lifted into space from the Earth. The Thompson Lunar Base would rely on a nuclear reactor for life support and materials processing, with the prospect of this being supplemented by solar power. The base would be located within easy reach of the lunar resources and Thompson raised the possibility of finding valuable ice deposits in permanently dark locations and caverns.

THE MOON'S BASIC DETAILS

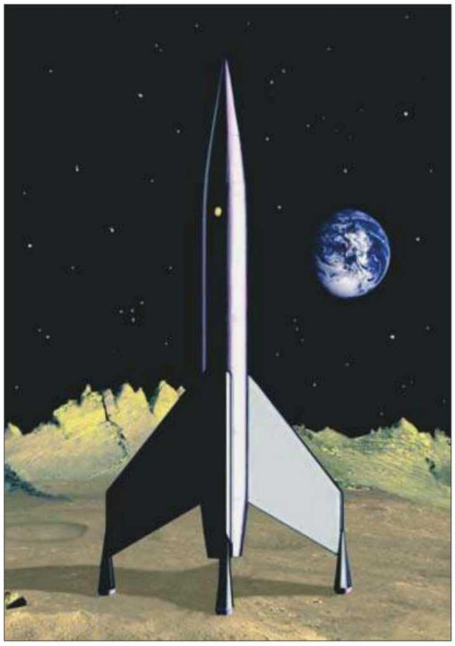
Mean distance from Earth:	238,855 miles	(384,400km)
Perigee:	225,744 miles	(363,300km)
Apogee:	251,966 miles	(405,500km)
Diameter:	2,159.88 miles	(3,476km)
Equatorial radius:	1,080 miles	(1,738.14km)
Polar radius:	1,078.6 miles	(1,735.97km)
Mean radius:	1,078.4 miles	(1,737.10km)
Rotational Period:	27.32 Earth Days	
Mean Surface Temperature:	-17.7°C	(0°F)
Max Surface Temperature:	137°C	(279°F)
Min Surface Temperature:	-169.6°C	(-273.3°F)
Inclination to ecliptic:	5.145°	
Inclination of rotational axis:	1.53°	
Highest point on surface:	Newton Crater rim	
Largest surface feature:	Mare Imbrium	
Equatorial surface gravity:	0.1654G	
Escape velocity:	1.47 miles per sec (2.38km per sec)	
Apparent visual magnitude:	-12.74	

In 1952 a series of captivating articles appeared in *Collier's Magazine* which described ideas for future space exploration and trips to the Moon. Written by Wernher von Braun, Willy Ley and Fred L Whipple, this impressive material was accompanied by some truly superb artwork by Chesley Bonestell, Fred Freeman, and Rolf Klep. It was suggested that the first Moon expedition would take place in 1977 and three massive spaceships, each weighing 4,370 tons (3,965 tonnes) after they had been assembled in orbit, would carry fifty astronauts to the lunar surface for a six-week period of exploration. Many aspects of this glorious vision were totally unrealistic and little more than wishful thinking, but the articles generated considerable public interest and helped to legitimise the idea of reaching the Moon. The following year von Braun, Ley and Whipple produced a book based on these articles called *Conquest of the Moon* (Viking Press 1953) which expanded on the concept of a substantial expedition.

A somewhat more realistic approach was taken by Arthur C Clarke who described a future lunar base in his book *The Exploration of the Moon* (Harper-Collins 1954). Using illustrations by fellow BIS member Ralph Smith, the text outlined plans to reach the Moon, followed by the establishment of an outpost using innovative inflatable igloos covered with moondust to aid thermal protection. As the base expanded, a large dome-shaped structure would be fabricated from blocks of 'lunar granite' and followed by the installation of a nuclear reactor, an algae-based air purification plant and a hydroponic farm. In time there would be monorails linking the various enclosed facilities and Clarke suggested an electromagnetic catapult to launch fuel into orbit, thus avoiding any wasteful landings and take-offs by interplanetary craft.

Project E-4

While the rocket designers and scientific visionaries remained hopeful that man would eventually walk on the Moon, there were others who had affordable short-term plans to exploit our natural satellite for political gain. In mid-1958 the Americans began a series of attempts to reach the Moon with small probes and this encouraged Keldysh and Korolev in the USSR to jointly submit proposals to the Soviet Central Committee for a series of more ambitious missions. Nikita Khrushchev gave the idea his full support and the Central Committee immediately rubber-stamped the



Right: **This illustration represents the kind of Moon ship that was frequently depicted in 1950s science fiction. Models appearing in magazine illustrations and movies were often based on wartime German missiles which looked more attractive than von Braun's more realistic post-war designs.** Bill Rose project. Three successful missions followed in 1959 with Luna probes making the first fly past of the Moon, the first impact on the Moon's surface and the first flight around the Moon to photograph most of its previously unseen far-side.

But there was another proposal made by the eminent physicist Jakov Borisovich Zeldovich (1914-1987) to explode a nuclear device on the Moon's surface. He argued that this would demonstrate Russia's technological abilities to millions of people around the globe. The scheme generated some initial opposition from members of the Central Committee, but it was finally approved and assigned the reference Project E-4. The idea of creating an explosion on the Moon's surface was not exactly new, but had grown in magnitude since 1916 when Robert Goddard considered the idea of delivering a magnesium powder charge to the lunar surface by rocket. This magnesium charge was expected to ignite on impact and he predicted it would be visible through a large amateur telescope. Several decades later Willy Ley expanded on the idea, and in 1945 the meteor specialist Dr Harvey H Nininger (1887-1986) raised the possibility of using a nuclear explosion to blast lunar soil samples towards the Earth.

Although Russia's Central Committee had expressed reservations about the E-4 project, Korolev's OKB-1 was requested to design and build the nuclear capsule, which by all accounts had quite a lot in common with a spherical sea mine equipped with multiple detonators using impact rods. The quoted weight of the E-4 capsule was approximately 880 lb (400kg) which was nominally more than Russia's first Luna E-1A probe that was the first man-made object to impact on the Moon's surface. So judging by the state of weapons technology at that time we can deduce that the nuclear device had a relatively low yield. A mock-up of the capsule was completed but major safety issues were raised about the launch of a live nuclear device and the consequences of its failure, perhaps resulting in the capsule falling on a foreign country or being stuck in orbit. Another problematic issue was providing foreign observatories with sufficient notice of the event, since details would have to remain secret until after the launch. These concerns would finally bring Project E-4 to an abrupt halt.

In America the same idea started to gain credibility during 1956 after the RAND Corporation secretly studied the idea of exploding a nuclear warhead on the Moon. In 1957 Dr Edward Teller (1908-2003), who invented the hydrogen bomb with Stanislaw Ulam, suggested detonating an atomic bomb above the Moon's surface to observe the effect of the explosion. This was followed by another proposal to bomb the Moon made by the designer Kraft Ehricke. Finally, scientists at the Jet Propulsion Laboratory (which was still under military control) conceived Project Red Socks, which included a plan to explode a nuclear bomb on the Moon to create a shower of debris that could be studied. These various recommendations led USAF Generals to seriously consider the idea as a way of generating interest in space operations and to demonstrate the USAF's technical abilities beyond the Earth.

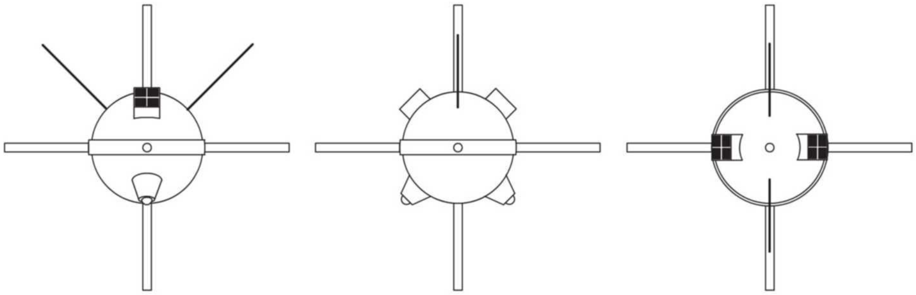
The plan was assigned the name Project A-119 and it was considered essential that as many people as possible witnessed the explosion. Classified studies began at the USAF's Special Weapons Center during April 1958 with additional scientific support from the Armor Research Foundation (which is part of the Illinois Institute of Technology). A number of well-known scientists were recruited to work on Project A-119 including Leonard Reiffel who later played an important role in the Apollo programme, the well-known astronomer Gerald Kuiper (1905-1973), and his student Carl Sagan (1934-1996) who would eventually become a major promoter of space exploration and the search for extraterrestrial intelligence (SETI). Edward Teller was also consulted about Project A-119 and he became a very enthusiastic supporter of the scheme, as he appears to have done with almost every plan to detonate a nuclear device.

While Project A-119 had very little scientific value, the Pentagon wanted the entire world to see that US missiles could hit targets anywhere. It was initially hoped to deliver a one megaton device to the Moon, although the substantial mass of an early thermonuclear warhead may have restricted the payload size to a lighter lower yield fission device. To ensure optimal viewing by observers, the explosion would take place on the Moon's night side somewhere close to the terminator.

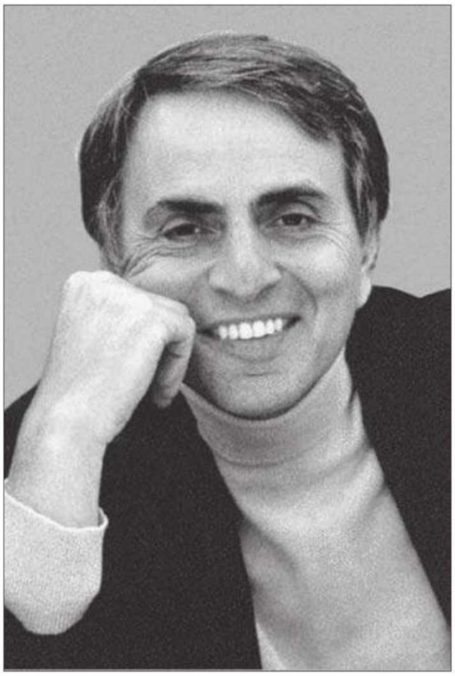
Launched on 4th October 1959, Luna 3 returned the first pictures of the Moon's previously unseen far side. Bill Rose

Early photograph of Jakov Zeldovich who proposed the idea of exploding a nuclear device on the Moon's surface to demonstrate the Soviet Union's technical and scientific capabilities. Bill Rose

Meteor specialist Dr Harvey Nininger who discussed the idea of setting off a nuclear explosion on the Moon to blast soil samples towards the Earth. Bill Rose



Top: **This drawing based on all available information represents the Soviet E-4 nuclear device which was developed for detonation on the Moon's surface.** Chris Gibson



Above left: **The late Carl Sagan was recruited to take part in the highly classified A-119 project.** NASA

Left: **The astronomer Gerald Kuiper was one of several well-known scientists who participated in the Pentagon's project to explode a nuclear device on the surface of the Moon.** NASA

However, with no atmosphere on the Moon the only thing visible would have been a short duration flash.

Details of the device or the launch vehicle are unknown, but it is believed that an uprated Atlas ICBM was chosen. Despite a number of unsatisfactory space launches and serious concerns about safety, by the late 1950s the USAF had acquired sufficient expertise to deliver a nuclear device to the Moon and Dr Reiffel remarked (many years later) that he expected the explosion to occur within two miles (3.2km) of the aim point. In an attempt to create scientific justification for Project A-119, Kuiper and Sagan were asked to consider the idea of studying the surface exposed by the explosion and the possible release of organic material. Sagan is known to have written a paper on the effects of radiological contamination which remains classified or has been destroyed. It has been reported that many of the scientists, including Dr Reiffel, had serious misgivings about the wisdom of this project and felt that the public's reaction would be decidedly negative. The politicians shared this opinion and the USAF was instructed to terminate the project in January 1959, with the details remaining hidden until 2000 when parts of the plan were finally declassified.

Fortress Luna

In January 1958 USAF Brigadier General Homer A Boushey (1909-2000) made a significant speech to the Washington Aero Club which provided a strong hint of how the Pentagon's chiefs were anticipating America's future in space. Boushey, who was an experienced aviator and something of a rocket pioneer, talked mainly about the future militarisation of the Moon. He outlined plans to construct missile silos beneath the lunar surface and described the use of an observatory to spy on the Soviets. He suggested that a base on the farside of the Moon would be permanently hidden from the Russians and said that any attack on the United States would be met with 'sure and massive retaliation' from the Moon some forty-eight hours later. Boushey rationalised that the Soviets would need to launch a pre-emptive strike against America's lunar facilities some two and half days before they attacked the US, which would provide their strategists with an insoluble problem. After outlining the military advantages of establishing an American presence on the Moon, Boushey declared that the Moon should be claimed as US territory.

He said 'We cannot afford to come out second in a territorial race of this magnitude. This outpost, under our control, would be the best possible guarantee that all of space will indeed be preserved for the peaceful purposes of man'. This statement with its 'Destination Moon' message contained some serious flaws, but it showed that the Generals hoped to secure the inner Solar System for America and they felt confident it could be done if adequate funding was forthcoming.

Lunex

Although the politicians finally decided that NASA would undertake a manned Moon mission, the USAF had been busily working on a set of highly classified plans for its own lunar programme. The initial USAF study with the codename SR-183 concentrated on establishing a small outpost which would be used to observe the Earth. A more ambitious study followed which received the designation SR-192 and part of this plan's title was 'military bombardment retaliatory capability from a Moon base'. These words pretty much say it all. An even more ambitious proposal was SR-182 which talked about the deployment of interplanetary vehicles carrying weapons. Offices for this programme were opened at Wright-Patterson AFB and many contractors were involved who included Boeing, Douglas, Republic and Martin. All parties agreed that the establishment of a lunar base would be technically feasible during the nineteen sixties and a figure of $20 billion was discussed. The outcome of these studies was a detailed scheme called the Lunar Expedition Program (Lunex), headed by Major General J R Holzapple.

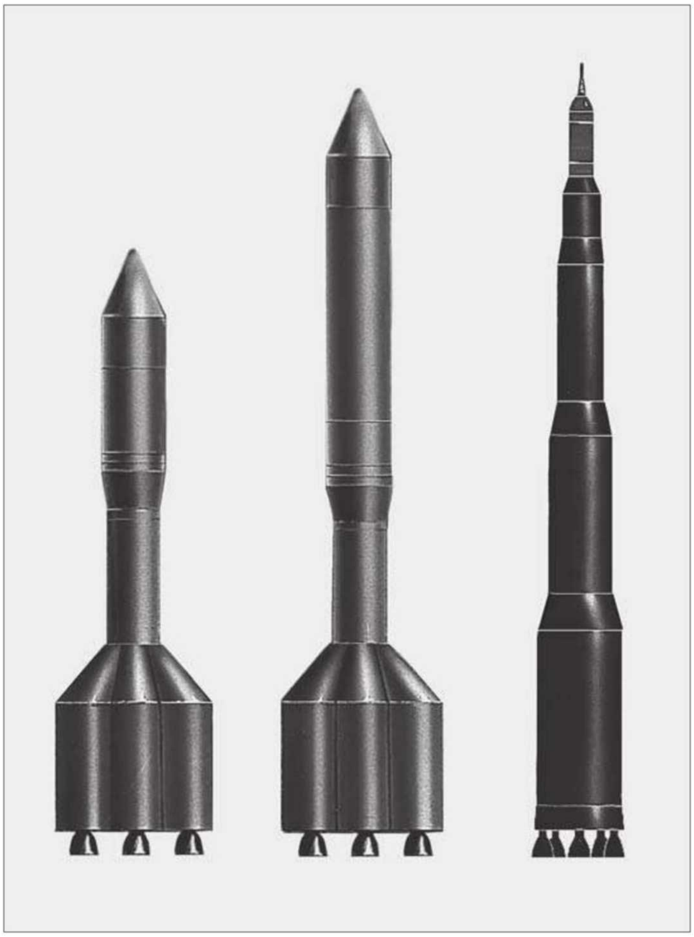
This ambitious and complex project would begin with a circumlunar flight in September 1966 and a manned landing by August 1967. A very sophisticated space transport system was proposed, which used a massive three-stage Nova rocket to launch manned and unmanned vehicles to the Moon. The USAF also intended to use the Nova to lift components into orbit for the construction of space stations and interplanetary vehicles capable of manned missions to Mars and Venus.

Direct manned flights to the Moon lasting two-and-a-half days would be undertaken with a very sophisticated three-man lifting body spaceplane that had an overall length of 52ft (15.8m). This delta-shaped vehicle would land in an upright position on the lunar surface using a special tail unit, which would eventually be used as a launch platform for the spacecraft's return journey to Earth. Following re-entry, the lifting body would make a conventional runway landing at a location such as Edwards AFB.

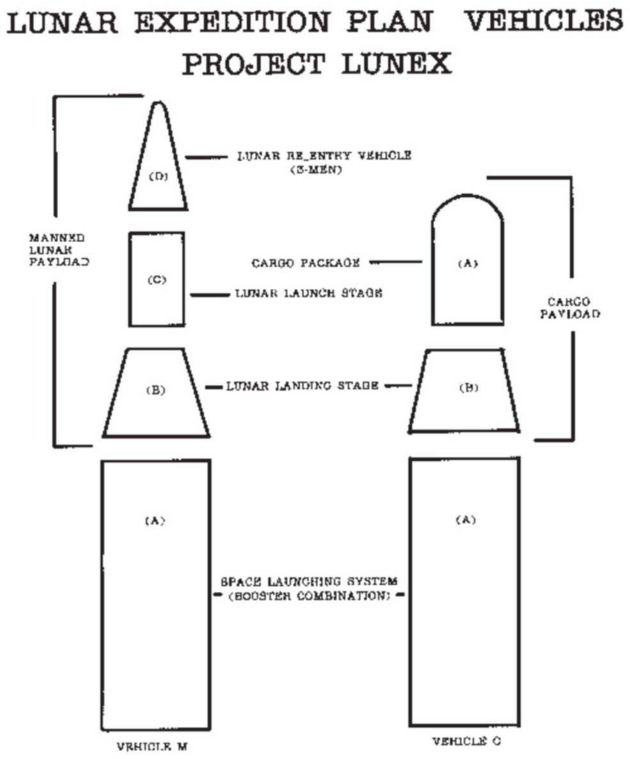
By January 1968 the USAF planned to have a permanently manned outpost on the Moon known as 'The Facility'. Few precise details of this Base are available, but it would have been assembled from cylindrical modules that were buried in trenches below the lunar surface. The deployment of weapons on the Moon is not well documented in the available Lunex proposals, but it is possible to envisage underground, fully (or partly) pressurised storage silos for nuclear-tipped missiles. When the Lunex programme began to gather momentum it was anticipated that one flight would take place every two weeks. Cape Canaveral was the favoured launch site, with the Corpus Christi Naval Air Complex being discussed as a secondary location. In 1961 the USAF's Space Systems Division released its classified Lunex study to senior officials. President Kennedy's advisors briefly reviewed the proposal, but their decision to use NASA for the Moon mission was never in question and the possibility of funding an alternative multi-billion dollar military project was unthinkable. As a consequence, the classified Lunex project was filed away and forgotten until late in 1999.

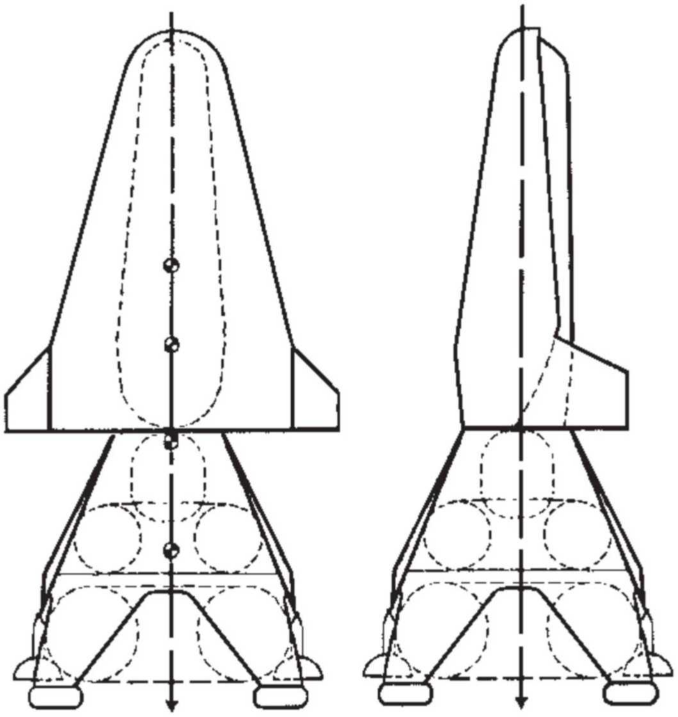
Right: **Homer Boushey addressed the Washington Aero Club in 1958 and outlined plans to construct missile silos beneath the Moon's surface to counteract future Soviet threats.** NASA

Bottom left: **If Project A-119 had met with approval it seems likely that a modified Atlas ICBM would have been used to deliver a small American nuclear device to the Moon.** USAF



Bottom right: **Early configurations for Nova launch vehicles. A three-stage Nova booster was proposed for the Lunex spaceplane, but this was originally conceived to support manned missions to Mars and Venus.** NASA

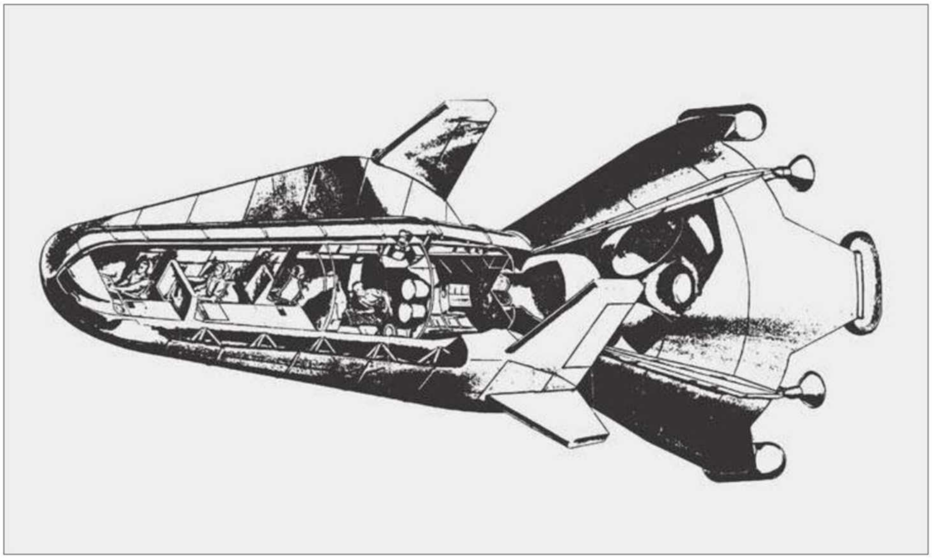




Project Horizon

Amazingly the USAF was not the only US military department with ambitions to take control of the Moon. The Army also investigated the idea in considerable detail under a top secret plan called Project Horizon. This ambitious proposal was developed by a team of former Peenemünde rocket engineers headed by Heinz Hermann Koelle, who worked for the US Army Ballistic Missile Agency (ABMA). Koelle reported directly to von Braun, although Lieutenant General Arthur G Trudeau who ran the Research and Development Group was in overall control. In an official US Army document dated 9th June 1959, Trudeau described the plan to establish a military lunar outpost as being, 'of critical importance to the US Army of the future', a view apparently shared by the Chief of Staff.

Trudeau went on to say that 'the full extent of the military potential (of a Moon Base) cannot be predicted, but it is probable that observation of the Earth and space vehicles from the Moon will prove to be highly advantageous. Military communications may be greatly improved by the use of a Moon-based relay station. The employment of Moon-based weapons systems against Earth or space targets may prove to be feasible and desirable. Moon-based military power will be a strong deterrent to war because of the extreme difficulty, from the enemy point of view, of eliminating our ability to retaliate.' He added 'To be second to the Soviet Union in establishing an outpost on the Moon would be disastrous'. Although nobody had flown in space yet, the CIA was confidently predicting that the Soviets would land a man on the Moon by 1965. East-West relations had almost reached rock bottom and US military planners were beginning to consider the possibility that future wars with the Communists might be fought in space.



Top left: **Lunex launch vehicle configurations.** USAF

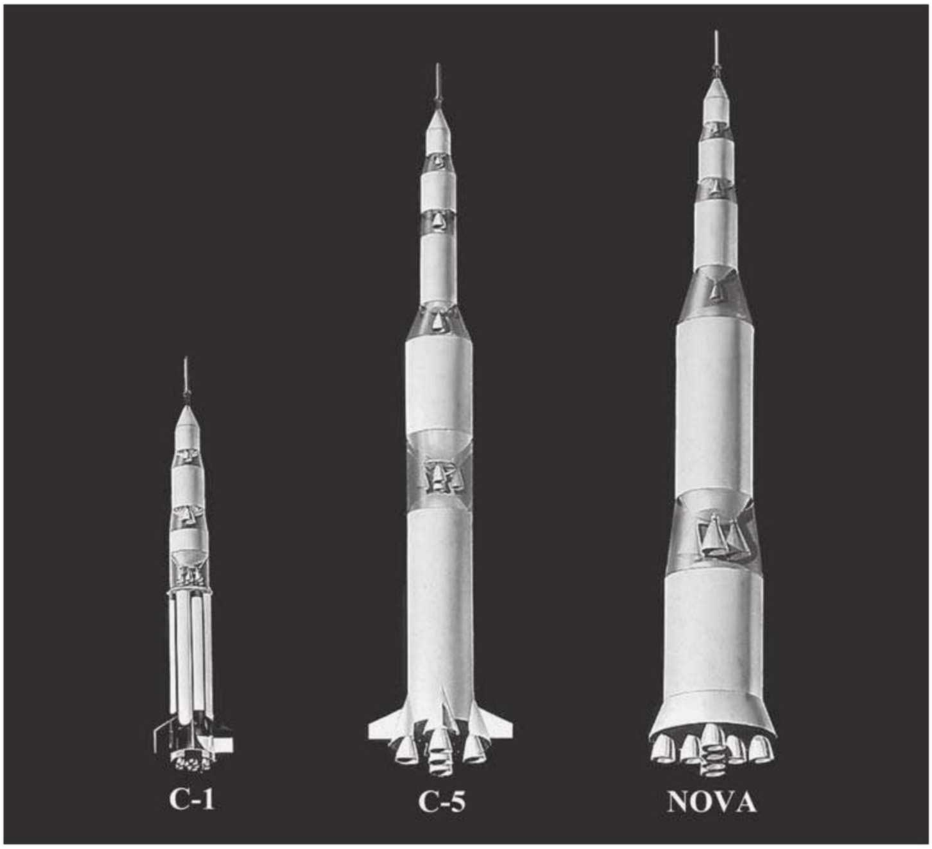
Top right: **Original USAF Lunex spaceplane drawing:** USAF

Left: **The advanced three-man Lunex lifting body spaceplane and attached landing module, showing internal detail. The Lunex spacecraft was designed to be approximately 53ft (16.1m) in length, its span was 25ft (7.62m) and mass 134,000 lb (60,781kg). The landing module would act as a launch platform and remain on the Moon when the spacecraft departed for Earth.** USAF

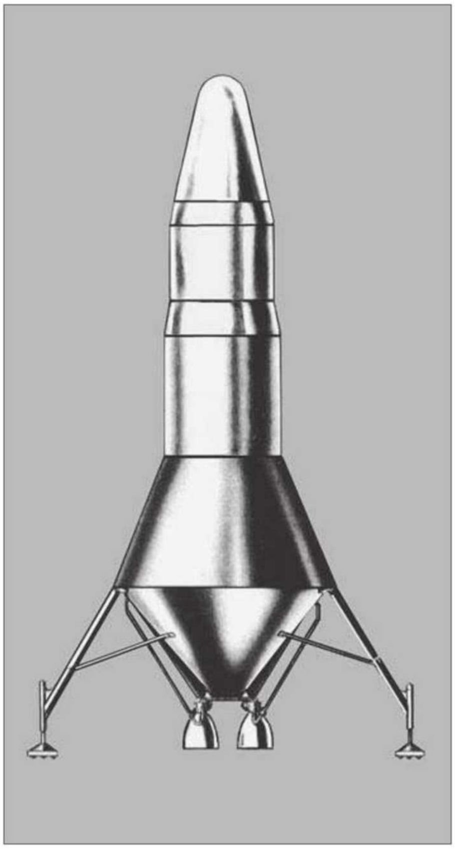
The military envisaged Project Horizon as an extremely rapid large-scale operation which would rely entirely on the use of the massive Saturn I and II rockets now in development. However, at this stage of planning the funding requirements were carefully glossed over as the price of this scheme would have run into many billions of dollars and far exceeded NASA's later Apollo programme. Under the Project Horizon proposal the first Army astronauts would reach the Moon by April 1965 and secure 'The Site' until the nine-man 'Construction Crew' arrived. The most favoured initial location for a Moonbase was the northern region of Sinus Aestuum, near Eratosthenes, which is in the general area of Copernicus.

That said, surface conditions were unknown at this time and it was accepted that the choice might alter after surveys had been conducted. Initially the base would be formed from an empty propellant tank that measured 20ft (6m) in length by 10ft (3m) in diameter. This would be buried in a trench to protect the occupants from extreme heat, micrometeorites and cosmic radiation. More tanks would be added to bring the total number of linked units to seven. These would house an accommodation section, recreation area, medical facility, communications/command centre and several research laboratories.

Right: **General Arthur G Trudeau was in overall control of the classified 1950s Project Horizon studies for the US Army.** US Army



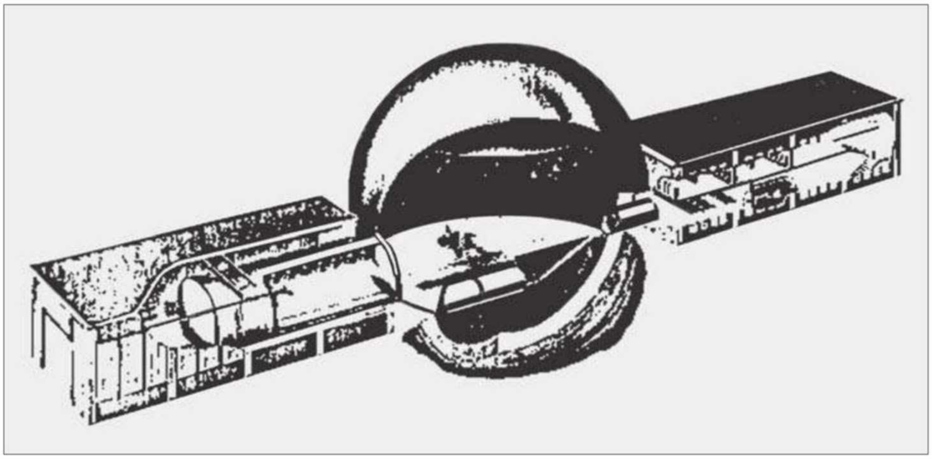
Bottom left: **Early comparison drawing showing rival Saturn and Nova launch vehicles.** NASA

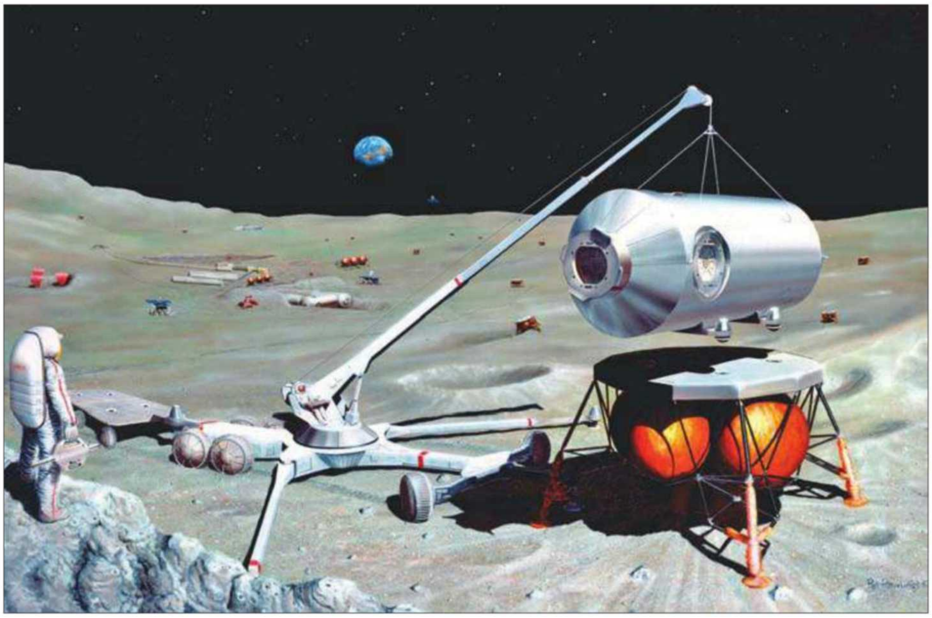


Bottom right: **Anticipated appearance of the Project Horizon spacecraft which was expected to have the capability of transporting as many as sixteen personnel to or from the Moon's surface. The Saturn rocket that was later selected for Apollo would have launched this spacecraft.** Bill Rose, but based directly on original drawings

The operation would move into high gear during Project Horizon's second phase and by November 1966 the Army expected to have launched at least 150 Saturn rockets transporting hundreds of tons of cargo to the lunar surface. By December 1966 the Moonbase would be fully functional, using four nuclear generators to power all of its systems. Estimates indicate that by the end of 1967 some 252 personnel would have flown to LEO and some forty-two would have travelled on to the Moon. Weekly Saturn rocket flights would continue throughout this phase and, to handle such a massive amount of traffic, new launch facilities were to be built in Brazil, at Christmas Island and possibly Somalia. Another aspect of the plan was to establish a robust communications network and the proposed 'Lunarcom' system would have required a series of satellites positioned in geostationary orbit around the Moon. Weapons systems were explored in some detail during this study, although close combat on the Moon's surface would use methods that sound very basic.

Today we might visualise 'Starship Troopers' equipped with recoilless assault rifles that fire rocket projectiles or directed energy weapons, but Project Horizon planned to issue US Army astronauts with a crude type of





scattergun. This weapon could best be described as a form of Claymore Mine on a pole that would be braced against the ground during discharge to absorb recoil. The shrapnel could rupture the spacesuits of enemy troops and US Army personnel would be protected against similar weapons with heavily armoured metal spacesuits. Batteries of missiles would be used to defend the Moonbase and nuclear weapons based on the Davy Crockett battlefield rocket would also be available. Proposed long-range offensive weapons systems for lunar deployment are not discussed within the available Project Horizon documents but, like the Lunex proposals, some sources show that dozens of nuclear-tipped missiles would have been stored within underground silos.

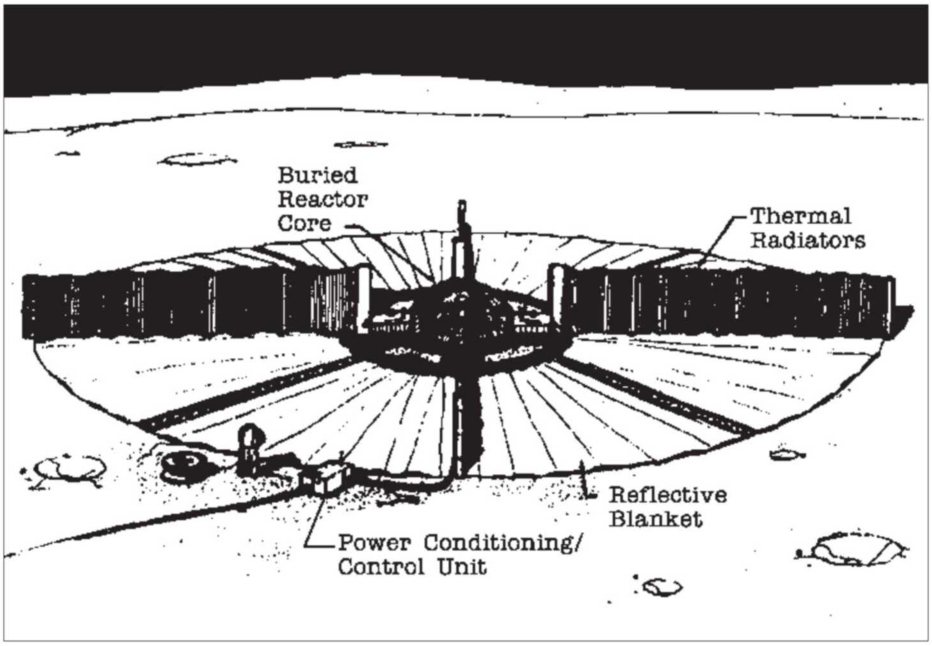
However, during 1958 the President's Scientific Advisory Committee (PSAC) chaired

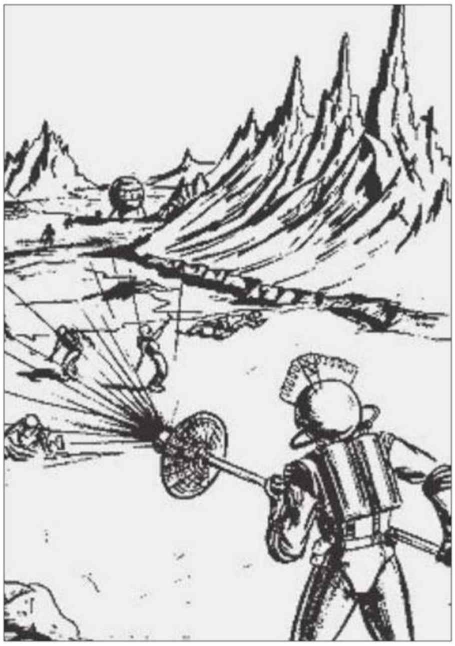
Top left: **One of the proposals for components of a buried lunar base produced for the Project Horizon study. The modules would be assembled in trenches and covered in lunar soil for protection.** US Army

Left: **Cylindrical modules used to form a manned lunar facility are lifted into position. This form of construction has been chosen for almost all initial Moon Base proposals.** NASA

Below left: **Project Horizon envisaged the use of four nuclear reactors to provide electrical power for the lunar facility. This illustration shows a buried 100kW nuclear reactor with thermal radiators on the surface to dissipate excess heat.** NASA

Below right: **Proposed hand-held weapon for Project Horizon personnel.** US Army





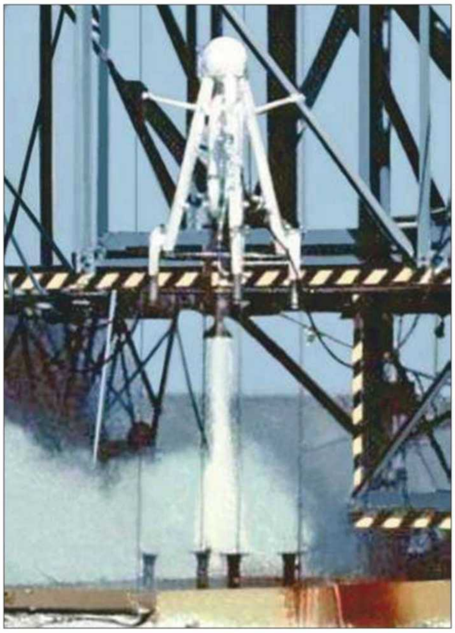
by Dr James R Killian (1904-1988) expressed concerns about the deployment of weapons in space and the establishment of military bases on the Moon. The Committee was also a strong proponent of civil space exploration and had been responsible for the creation of NASA. The Project Horizon study was completed in mid-1959 and presented to the Eisenhower Administration, where it received a cool reception. With a Presidential Election approaching it would seem that some senior Army officials remained hopeful that Horizon would receive a more favourable reception if Republican candidate Richard M Nixon took office. But Kennedy won the 1960 election and his Administration was equally committed to the peaceful use of space. The Army's plan to build bases on the Moon was rejected and most of the US Army staff who worked on Project Horizon were eventually transferred to NASA's Apollo programme. The documentation for Project Horizon was then filed away and would remain classified for the next forty years, although the excellent Saturn rocket was made available to NASA.

As a footnote to these extraordinary plans drawn up by the USAF and US Army, it's worth mentioning that in 1961 the US Navy considered placing a dog on the Moon by 1963, bringing back a soil sample by 1964 and landing a Navy astronaut on the lunar surface during 1967. Headed by Dr Nicolaides at China Lake, the Navy's Lunar Project's Office also produced a detailed plan for the construction of a Moon base, although further development stopped when Lunex received the thumbs down.

After the cancellation of the Apollo lunar programme in 1972, NASA continued to sponsor low-level studies of future manned Moon missions during the remainder of the century. Perhaps the most interesting (and realistic) proposal was the Early Lunar Access (ELA) plan undertaken during 1992-1993 in conjunction with the European Space Agency. The main contractor for ELA was General Dynamics who suggested an advanced two-man version of the Apollo capsule combined with a landing and habitation unit. Utilising the Space Shuttle and a Titan 4 or Ariane 5 rocket, it was hoped to undertake a return mission by 2000 with a two to three-week stay on the surface. This affordable plan generated considerable interest, but the Shuttle and ISS were soaking up most of NASA's budget and a resumption of manned missions to the Moon was an unrealistic aspiration at that time.

Russians on the Moon

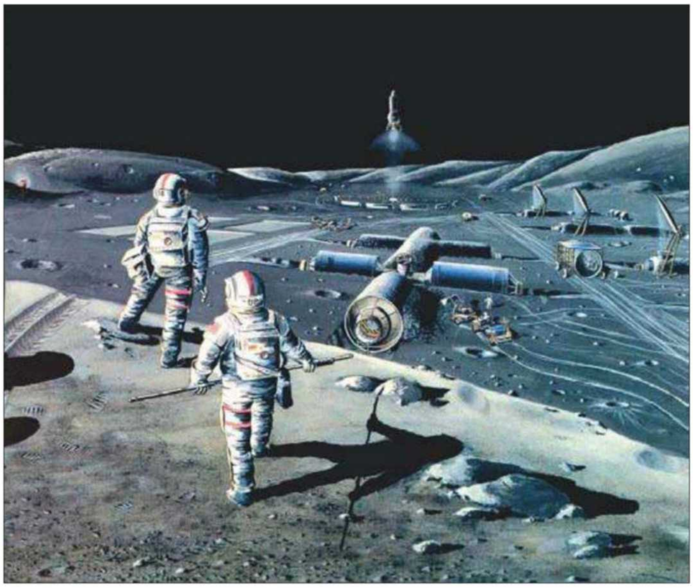
In Russia work began on a secret Moon landing project during the late 1950s, although the programme wasn't given any kind of priority until Space Chief Sergei Korolev met directly with Premier Nikita Khrushchev at the Kremlin on 24th March 1964. Khrushchev soon decided that a manned Moon mission was essential and he approached the Central Committee for massive funding. The Central Committee dithered because it knew Khrushchev would be deposed shortly, but all members finally agreed that the Americans couldn't be allowed to reach the Moon first. So, on 3rd August 1964 the Kremlin issued Command 655-268 which secretly instructed Korolev to proceed with a full-scale Moon project. Subsequently, large sections of State Industry were mobilised, although many Soviet officials felt that the promise of a manned landing in 1968 was rather unrealistic

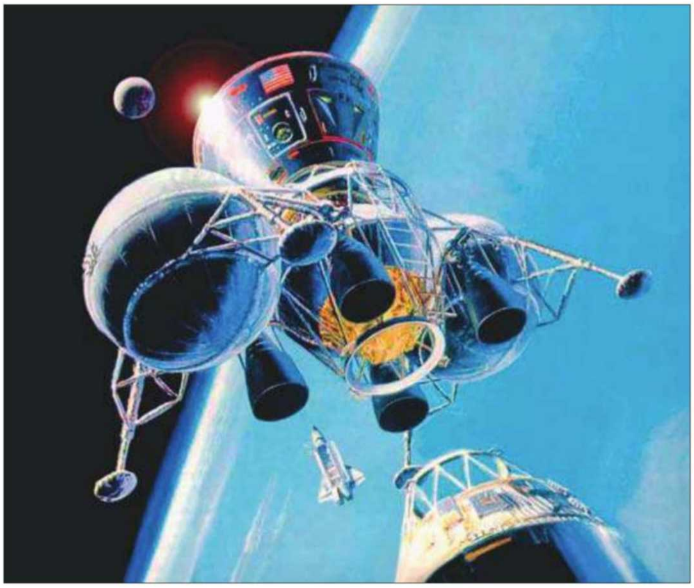


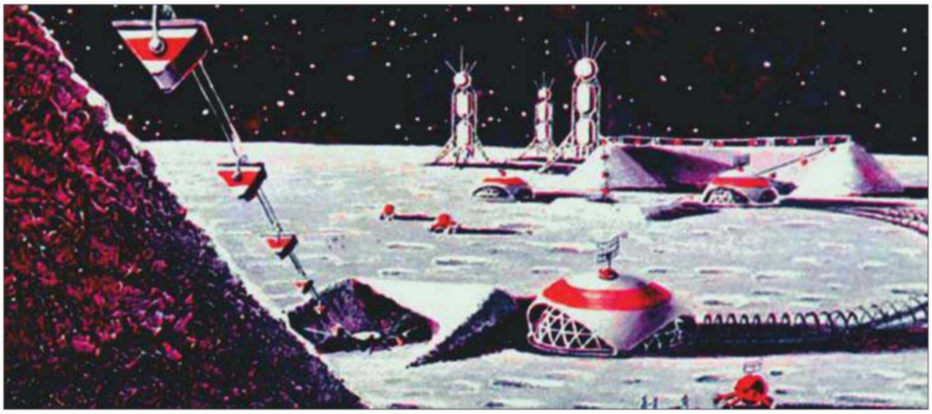
Above: **Tested at China Lake in 1961, the US Navy's Soft Landing Vehicle (SLV) was the first step in a series of proposals to place a Navy astronaut on the Moon's surface by 1967. The scheme was dropped at the end of 1961 when NASA was authorised to proceed with the Apollo programme.** US Navy

Bottom left: **Assembled from cylindrical modules, this Moon base concept shows an almost completed outpost, with work in progress to cover the units with lunar soil to provide protection against radiation and micrometeorites.** NASA

Bottom right: **The proposed Early Lunar Access vehicle in orbit. Conceived by General Dynamics as part of a study for NASA in association with the European Space Agency (ESA), this early 1990s proposal was built on the Apollo project as a fast and relatively inexpensive means of returning to the Moon by 2000.** NASA







Left: **A very early concept for a Soviet lunar city produced by Aleksei Leonov and Andrei Sokolov.** Bill Rose

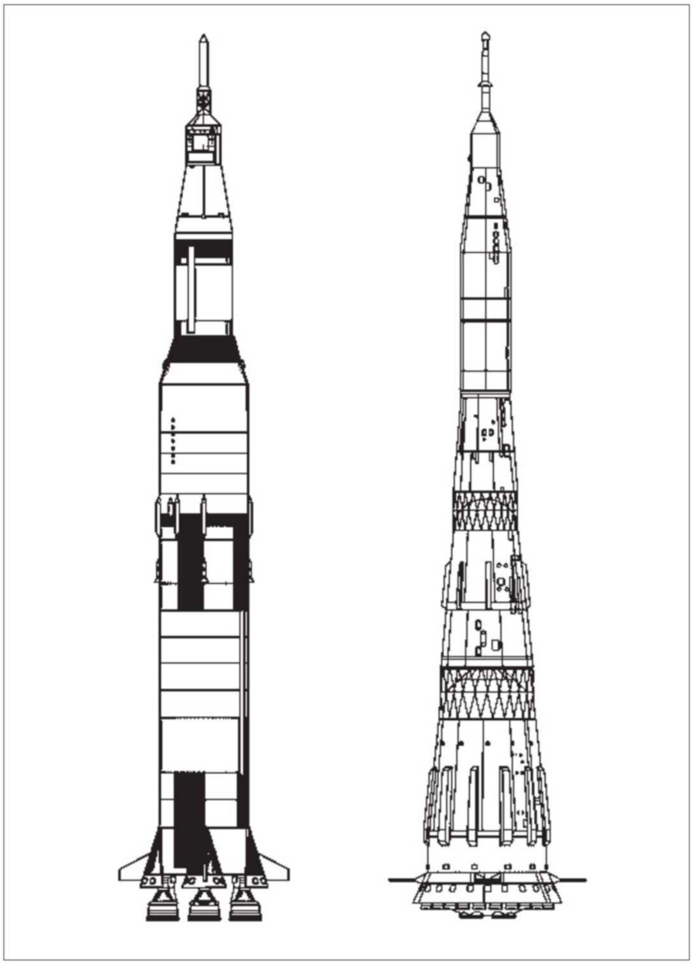
Bottom left: **Two huge rockets designed to place men on the Moon – the US Saturn V (left) and the Soviet N-1 are shown to scale.** NASA

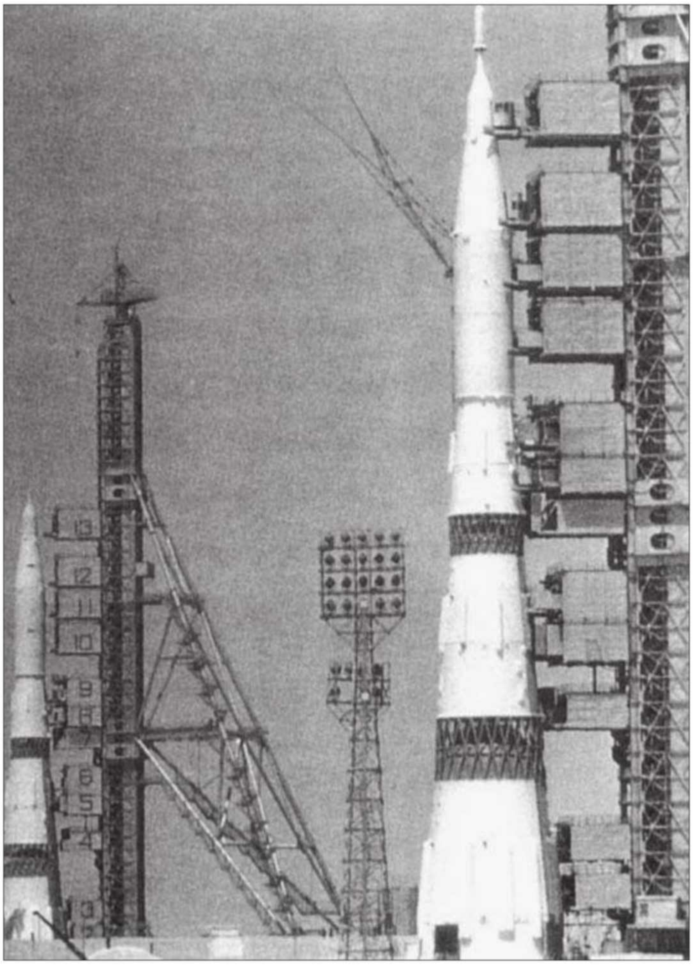
Bottom right: **A huge launch complex was built at Baikonur to handle the massive N-1 rocket, which was essentially the Soviet equivalent of the Saturn V.** via NASA

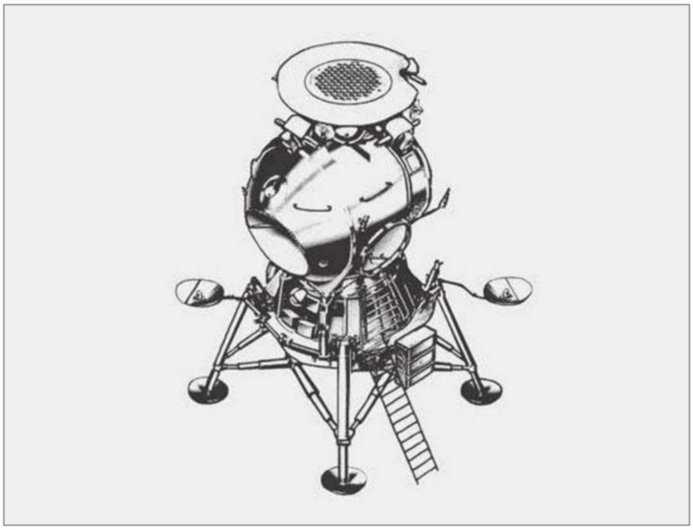
and it was better to opt for a less demanding circumlunar flight by 1967. Few Westerners outside senior Pentagon or CIA circles would have known that the Soviets were preparing to land a man on the Moon, although there was a widely held belief that they might get there first.

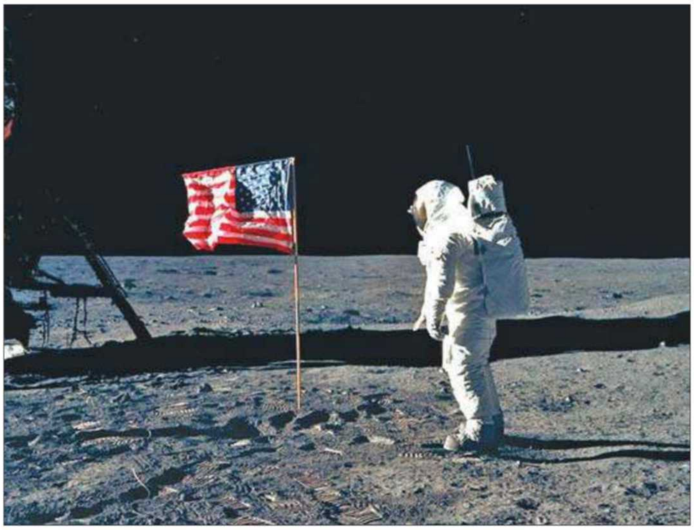
Facilities had been built at Baikonur to handle the huge N-1 rockets that almost equalled the American Saturn V in performance, and these would be responsible for putting Russians on the Moon. Eighteen cosmonauts were secretly trained for the first Moon landing and at least four lunar descent vehicles, designated LK and somewhat similar in appearance to the American LM lunar module, had been built. After the LK had landed one cosmonaut would have stepped onto the lunar surface and stayed out there for about four hours.

If this and further landings proved successful, a small lunar outpost would have been built by the mid-1970s. The design of a base had been under leisurely development by OKB-1 since the end of the 1950s and Korolev had written an article for Pravda in 1960 (under a pseudonym) that outlined the future possibilities of establishing a manned facility on the Moon. But Korolev's bureau was too busy to become involved in any formal studies for a Moon base and the designer turned to his friend Vladimir Pavlovich Barmin (1909-1993) who headed GSKB SpetsMash (Special Machine-Building Design Bureau) where rocket-launching equipment and missile silos were developed. Apparently the idea of constructing a Moon base was frequently a topic of informal discussion between the two men and, soon after Korolev's death in 1966, GSKB SpetsMash received an official request to begin a detailed Moon base study.









To handle the project Barmin formed Department 29 under the management of A P Chemodurov who was given a wide brief to investigate the scientific and military requirements for a lunar outpost. Many prestigious institutions became involved with this project, examining construction methods, space transport, life-support, energy, geology and the choice of location. Known as the Long Term Lunar Base (DBL), the first major proposal was completed at the end of 1969. Chemodurov suggested that the outpost should be developed in three stages, starting with four personnel and rising to twelve after one year. Cylindrical modules would be transported from Earth to form the base's main structure. On arrival these would be 14ft 9in (4.5m) long but pressurisation would cause the two components to slide apart until a length of 28ft (8.6m) was reached. The maximum diameter was 10ft 9in (3.3m) and it was planned to assemble nine interconnected modules in trenches and then cover them with lunar soil to protect personnel from radiation and meteorites. Power would be nuclear and this was considered an absolute necessity during the long lunar nights (lasting 14.5 Earth days) when solar energy would not be available. Cargo and personnel would be transported to the Moon using Proton or N-1 rockets and, should a decision be made to expand the base, huge underground tunnels and chambers would be formed with special boring machines and nuclear explosives.

Apparently GSKB SpetsMash built a full-sized habitation module which was used for engineering development and to show visiting officials. Either this unit or another module was also used for psychological trials with volunteers at the Institute for Bio-Medical Problems (IBMP). However, the first N-1 rocket malfunctioned soon after lift-off on 21st February 1969 and three more attempts to launch these huge vehicles ended in disaster, leading to the N-1 being virtually abandoned at the end of 1972.

In 1974 Valentin Glushko was appointed the head of OKB-1 (later NPO Energia) and, as such, he occupied the most important position in the Soviet space programme. One of the first things that Glushko did was to formally scrap the N-1 rocket programme. But he kept the idea of a lunar base alive and assigned a new department to study a permanent lunar outpost, which would be supported by a newly-designed heavy launch vehicle called Vulkan. Utilising the work already undertaken by GSKB SpetsMash, the new project was named Zvezda (Star) and the first expedition would land on the Moon in 1980. An outpost would be developed in three phases, as proposed by Chemodurov, with about 130 tons (118 tonnes) of hardware being delivered to the Moon by the mid-1980s.

According to Aleksandr Yegorov, who worked for Vladimir Barmin as a designer and was closely involved with the Moon base programme, there was a plan considered by the Ministry of Defence to utilise the outpost as a military headquarters. Speaking to the *Novaya Gazeta Weekly* in September 2004, Yegorov claimed that the Moon was considered the ideal location for a strategic headquarters, although this expansion of the original proposal was simply beyond the financial means of the Soviet Government. Unfortunately for Glushko, the cancellation of America's Apollo programme had an increasingly negative effect on Russia's ambitions to reach the Moon, and this was followed by a badly judged decision to duplicate the forthcoming US Shuttle. Glushko tried to maintain interest in manned missions to the Moon, suggesting the use of Energia launch vehicles for several small-scale expeditions. But the disastrously expensive Buran shuttle went ahead and any hopes of putting Russians on the Moon were dashed. Undoubtedly, Glushko could have had his Moon base for the amount of money spent on matching the American spaceplane.

Top left: **The LK (Lunniy Korabl – lunar craft) was Russia's Moon landing vehicle. It was designed in the 1960s by Korolev's bureau to place a single cosmonaut on the Moon's surface before the Americans. Smaller than the Apollo LM and somewhat cruder in design, the LK was successfully tested in Earth orbit.** NPO Energia

Top right: **In July 1969 the Moon race came to an end and a US flag was planted on the lunar surface.** NASA

Right: **In 1974 Valentin Glushko was appointed as head of OKB-1, which was later re-named NPO Energia.** Bill Rose

Glossary

AAM Air-to-Air Missile.

Ablation Erosion of material used for heat shielding during re-entry.

ABM Anti-Ballistic Missile.

Aeroshell An external covering used for protection against atmospheric entry heating.

AFB Air Force Base.

Apogee The point in a terrestrial orbit farthest from the Earth.

ASAT Anti-satellite.

BAC British Aircraft Corporation.

Ballute The name is derived from the words balloon and parachute, referring to a small tethered balloon used as a high-speed, high-altitude braking device.

BIS British Interplanetary Society.

Black Projects Highly classified, secretly funded programmes usually involving the development of new military systems. These can remain hidden for years, perhaps decades, sometimes progressing no further than studies.

BOR Bezpilotniye Orbitainiye Raketoplan. Small experimental unpiloted Soviet orbital rocketplane.

CIA Central Intelligence Agency.

CNES Centre National d'Études Spatiales – French Space Agency.

Cross Range The manoeuvring distance on either side of a re-entry path that is available to a spacecraft.

DARPA US Defense Advanced Research Projects Agency.

Delta v A change in velocity during a space mission.

DEW Directed-Energy Weapon – a high-powered laser or microwave device.

DoD US Department of Defense.

Ekranoplan An air vehicle resembling an aircraft and designed to fly just above a flat surface using the principle of 'ground effect'. In Russian the Ekranoplan was conceived by the Soviet designer Rostislav Alexeev and several prototypes were secretly tested on the Caspian Sea during the Cold War. Although an interesting concept, technical problems have prevented the Ekranoplan from entering civil or military use.

ELINT Electronic Intelligence.

EMP Electromagnetic Pulse.

ESA European Space Agency.

Exoatmospheric Above the Earth's atmosphere, at an altitude of more than 62.1 miles (100km). This transition point from atmosphere to space has been accepted by the Fédération Aéronautique Internationale (FAI), who maintains the international standards for aeronautics and astronautics.

FDL Flight Dynamics Laboratory, USAF.

Geostationary Orbit An orbit that keeps exact pace with the Earth's rotation and allows a spacecraft to remain in a fixed position above the planet.

Gimballing Use of a system of pivots that allows directional control of a rocket engine.

Hypergolic A term applied to a fuel and oxidant that ignite spontaneously on contact with each other.

Hypersonic Generally accepted as a speed above Mach 5 (Mach 1 = the speed of sound).

ICBM Inter-Continental Ballistic Missile.

IRBM Intermediate Range Ballistic Missile.

ISS International Space Station.

JPL Jet Propulsion Laboratory, USA.

Kinetic Energy Weapon Kinetic energy contained by a body in motion and converted into explosive force due to impact.

Laser Light amplification by stimulated emission of radiation – monochromatic visible/invisible light.

LEO Low Earth Orbit.

Lifting Body A re-entry vehicle utilising lift, which falls somewhere between a semi-ballistic shape and a winged craft.

LM Lunar Module.

LOX Liquid Oxygen.

LPM Lines Per Millimetre. A photographic term used to define image resolution.

MoA UK Ministry of Aviation, 1959-1967.

MoD UK Ministry of Defence, 1964-Present Day.

MoS UK Ministry of Supply, 1939-1959.

Moderator A material (such as graphite or beryllium oxide) used in a nuclear thermal reactor to slow the neutrons from their fission exit speeds to thermal energies.

Mt Megaton.

NACA National Advisory Committee for Aeronautics.

NASA National Aeronautics & Space Administration.

NERVA Nuclear Engine for Rocket Vehicle Application.

NOSS Naval Oceanic Surveillance Satellites.

NPO The Russian term for a Scientific Production Organisation. The approximate translation is 'Corp' or 'Ltd'.

OKB Opytnoe Konstruktorskoe Byuro – Soviet Experimental Design Bureau.

OK-M This was an official Soviet request for preliminary studies into the feasibility of building a smaller version of the Buran spaceplane issued in the 1980s. The intention was to eventually use this vehicle as a replacement for the Soyuz and Progress vehicles. NPO Energia and OKB Molniya were the main organisations involved in this project, with Energia favouring a conventional rocket launch using a Zenit booster and Molniya preferring to air-launch using an adapted Antonov An-225. This second system led directly to the MAKS spaceplane programme.

Orbital Period The time taken for a satellite to make a complete revolution around another body.

Orion Spacecraft Previously called the Crew Exploration Vehicle (CEV), this is America's manned replacement for the Space Shuttle.

Parking Orbit Orbit in which a spacecraft awaits the next phase of its mission.

Payload Normally cargo or equipment but can refer to military ordnance.

PBR Particle Bed Reactor.

Perigee The point in a terrestrial orbit (by an artificial satellite, natural body, the Moon, and the like) that is nearest the Earth.

Project Orion A spacecraft designed in the 1950s using small nuclear explosions for propulsion detonated behind a pusher plate.

Reaction Control System Small system of gas jets used to adjust the orientation of a vehicle in space.

RAE Royal Aircraft Establishment.

RLM Reichsluftfahrtsministerium (Wartime German Air Ministry).

ROC Royal Observer Corps.

Rods From God Heavy metal rods dropped from orbital height at hypervelocity with their kinetic energy being converted into explosive force.

SDI Strategic Defense Initiative.

Slush Hydrogen Slush hydrogen is a semi-solidified version of liquid hydrogen used as a rocket propellant. Its density is 20% greater than in liquid form.

Specific Impulse (IsP) A method of evaluating a rocket engine's efficiency. The thrust of a rocket engine in lb (or kg) divided by its propellant consumption in lb/sec (kg/sec).

SRW Strategic Reconnaissance Wing.

SSTO Single Stage To Orbit.

STS STS – Space Transportation System – a NASA term. An STS reference (for example STS-33/51-L) is given to every Shuttle mission.

Sub Orbital A high-altitude rocket flight that does not achieve orbit.

TFW Tactical Fighter Wing.

Tons/tonnes Throughout this book the value for 'ton' equates to an American short ton, which equals 2,000 lb. The metric tonne is 1,000kg, and the conversion factor is 0.9072.

TsAGI Tsentrahl'nyy Aero-i Ghidrodinameeche-skiy Institoot (Central State Aerodynamic and Hydrodynamic Institute), Zhukovsky.

TSTO Two Stage To Orbit.

USAAF United States Army Air Force.

USAF United States Air Force.

VfR Verein für Raumschiffahrt – Society for Spaceflight, Pre-war Germany.

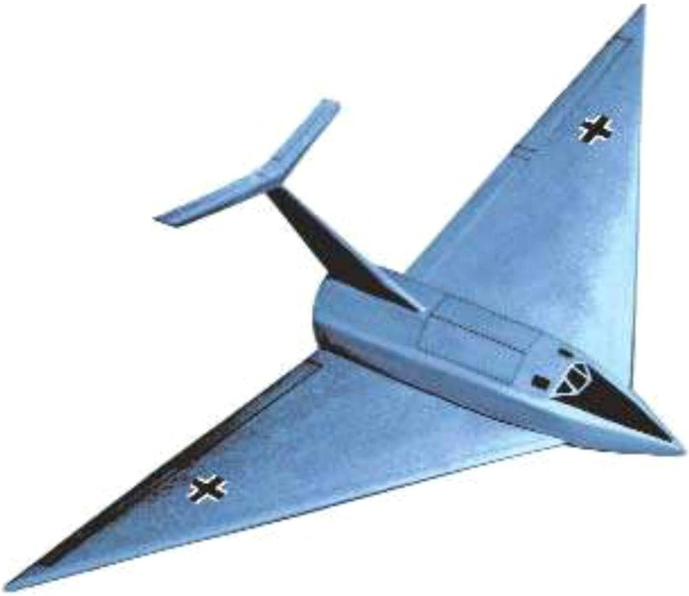
VTO Vertical Take-Off.

VTOL Vertical Take-Off and Landing.

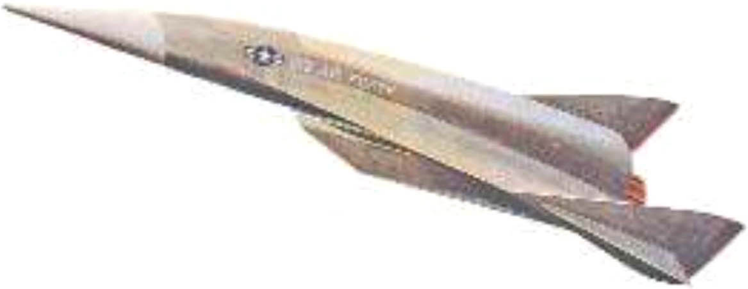
WSMR White Sands Missile Range.

Index

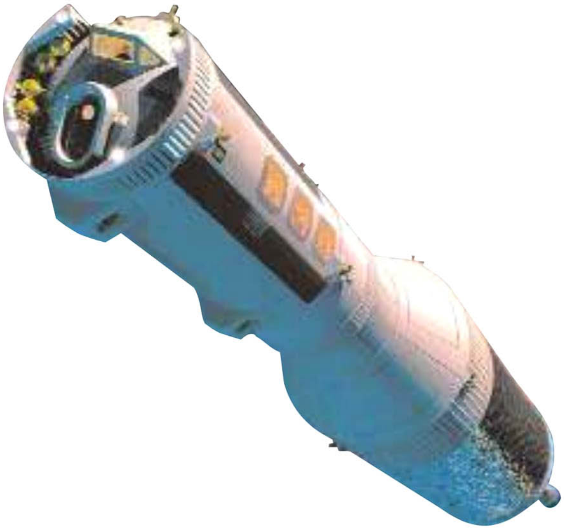
2001 – A Space Odyssey Movie 11, 179
A1 Rocket 21
A2 Rocket 21
A3 Rocket 21
A4 Rocket 9, 16, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 39, 41, 42, 63, 64, 65, 66, 68, 70, 79
A4b Rocket 25, 26, 27
A5 Rocket 18, 21, 22, 26, 66
A6 Rocket 25, 26, 27
A7 Rocket 25, 26
A8 Rocket 25, 29
A9 Rocket 27, 31, 35, 37, 41
A10 Rocket 27, 41, 65
A12 Rocket 28
Aerospaceplane McDonnell Douglas 127
Almaz Space Station 94, 95, 155, 161, 162, 163, 166
ALSV – Air-Launched Sortie Vehicle 133, 134, 135
Amerika Bomber (see Sänger-Bredt Spaceplane) 33, 36
Andrews, John 138
Apollo X 97
Armor Research Foundation 181
ASSET 120, 121
Aurora 129, 131, 132, 133, 137, 138, 142, 159
Ba 349A Natter (Adder) Interceptor 19, 20
BAC Delta-Winged Spaceplane 48, 49
Bachem, Dr Erich 18
Barmin, Vladimir Pavlovich 188, 189
Big Gemini – Big G 95, 97
BIS Moon Study 8, 41
Black Arrow 46, 54
Black Prince 46
Blackstar SR-3 Secret US Spaceplane System 139
Blackswift Hypersonic Vehicle 142
Blue Eyes (see Aurora) 138
Blue Gemini 92, 93
Blue Steel 46, 47, 48
Blue Steel Manned 47, 48
Blue Streak 45, 46, 50, 56, 57
BoMi Bell 82, 83, 84, 85, 90
Bond, Alan 57, 58, 60, 179
Bono, Philip 98, 99, 100, 101
BOR Test Vehicles 90, 151, 153, 154, 156
Boushey, Brigadier General Homer A 182, 183
BP 20 Bachem Rocketplane 19
Brass Bell Spaceplane 84
Bredt, Irene 32, 37
Brilliant Buzzard (see Aurora) 138
Brilliant Pebbles 167
Brown Group 77
Buran (Ramjet Missle) 26, 37, 145
Buran (Spaceplane) 11, 12, 60, 148, 152, 153, 154, 155, 156, 157, 158, 159, 162
Burya Ramjet Missile 26, 37, 145
Caleb Launch Vehicle 105, 106, 107
Canadian Arrow Rocket 31, 32, 81
Chelomei, Vladimir Nikolayevich 148, 149, 154, 155, 161, 162, 163, 164, 167, 168, 175
CL-612 Lockheed Spacecraft 90
CL-639 Lockheed Spacecraft 123, 124
CL-651 Lockheed Test Vehicle 125
CL-839-26-9 Lockheed Hypersonic Vehicle 128
CL-839-28 Lockheed Hypersonic Vehicle 81
CL-1047 Lockheed TSTO System 123
Clarke, Arthur C 41, 179, 180
Copper Canyon 133, 135
Daedalus Starship 57, 179
D-558 Douglas 73, 74
DC-X 103, 104
DC-X2 104
DC-Y 104
de Hoffman, Frederick 169, 175
Deep Space Force 177
Destination Moon Movie 10
DF-1 (Dong-Feng 1) Missile 31
DFS 346 70, 145
Dornberger, Walter 15, 25, 27, 28, 37, 63, 64, 68, 76, 77, 81, 82, 84, 137
Drake-Carmen Manned Research Vehicle 77
Dyson, Freeman 176, 177, 178, 179
EF 127 Junkers 'Walli' 19
Everett, Cornelius 175
Excalibur X-Ray Laser Weapon 116, 117, 173
Explorer IV Satellite 107
FDL-5 124, 139
Fi 103 Flying Bomb 18, 22, 24
Fi 166 Rocket Fighter Project 18, 19, 20
Francis, Hugh 47, 55, 57
Frau im Mond Movie 8, 14
Gemini B Re-entry Capsule 92, 93, 94, 97, 161, 163
Gibson, Chris 129
Gliding Spaceplane (PKA) 147, 148
Glushko, Valentin 145, 151, 155, 156, 174, 189
Groom Lake Test Site (Area 51) 131, 132, 138, 139, 142
Gröttrup, Helmut 9, 27, 29, 143
Hawker Siddeley TSTO 55, 56, 57
He 112 15, 16
He 176 16, 17, 18
Hermes 65, 66, 68, 127, 145
High Virgo 107
HL-10 Northrop Lifting Body 118, 119
Hogle, Brigadier General Walter S 129, 130
Holzapple, Major General J R 182
Hot Rod 177
HOTOL 57, 58, 59, 60, 61, 62, 179
HSS Heavy Space Station – Korolev 160
HYTID 126
HYWARDS 83, 84
Interim HOTOL 60
International Space Station (ISS) 12, 90, 98, 165
IS Istrebitel Sputnikov 166, 167, 168
Isinglass 126, 127, 142
Ithacus Junior Rocket Transport 99, 100
Ithacus Senior Rocket Transport 100, 101
Jupiter Missile 69, 70
Keldysh Spaceplane 36, 37
Keldysh, Mstislav Vsevolodovich 36, 37, 147, 156, 180
Kinetic Energy Weapons 117
Kiwi-A Nuclear Engine 169, 170
Kiwi-TNT 170
Koelle, Heinz Hermann 184
Korolev, Sergei Pavlovich 10, 31, 143, 144, 145, 146, 147, 148, 151, 160, 161, 164, 174, 175, 180, 181, 187, 188, 189
Kotcher, Ezra 70
Kracht, Felix 70
Kuiper, Gerald 181, 182
LACE – Liquid Air-Cycle Engine 57
Lafferenz, Otto 28
Lapcat 62
Ley, Willy 7, 15, 180, 181
LKS Spacecraft 154, 155
LM CSD – Lunar Module for Covert Space Denial 98
Lockspeiser, Sir Ben 70, 71
M-48 Russian Spaceplane 147
M.52 Miles 70, 71
M2-F1 Lifting Body 118
M2-F2 Lifting Body 118, 119
M2-F3 Lifting Body 118, 119
Megaroc 41, 42, 144
MiG-31D *Foxhound* 168
Milburn, Captain Apt 76
MOL – Manned Orbital Laboratory 89, 92, 93, 94, 95, 96, 97, 114, 161, 166
MTSS – Military Test Space Station 93
MUSTARD – Multi-Unit Space Transport & Recovery Device 50, 51, 52, 53, 54, 55
Myasishchev, Vladimir Mikhailovich 145, 146, 147, 148, 150
NASP – National Aerospace Plane 135, 136, 138, 139, 159, 160
NERVA – Nuclear Engine for Rocket Vehicle Applications 169, 170, 171, 173, 174, 178
Nike Zeus 108
Nonweiler, Terence Reginald Forbes 44, 45, 46
Nonweiler Waverider 44, 56, 147
Noordung, Hermann 8, 38, 39
North Sea Sighting 129, 130
NOTS-EV-1, Notsnik 104, 105, 106
NRX Nuclear Engine 171, 173
Oberth, Hermann 7, 8, 14, 15, 32, 37, 38, 39
Oberth Orbital Mirror 39
Operation *Hydra*, RAF 22, 23
P.1077 Heinkel 'Julia' 19
Parkinson, Robert 58, 60
Patriot Advanced Capability (PAC) 3 Missile 111
Peenemünde 15, 16, 18, 19, 21, 22, 25, 27, 28, 29, 37, 39, 63, 64, 66, 81, 82, 143, 184
Pegasus Rocket Transport 99
Phoebus Nuclear Engine 171, 173
Point Loma, California 177
Polyus 163, 164, 165, 168
Project A-119 181, 182, 183
Project Apollo Spacecraft/Programme 6, 9, 11, 12, 20, 41, 89, 91, 93, 94, 95, 96, 97, 98, 99, 102, 118, 119, 137, 141, 171, 173, 178, 181, 185, 187, 189
Project Dachs 27
Project E-4 180, 181, 182
Project FALCON 141, 142
Project Gemini 89, 91, 93
Project Horizon 184, 185, 186, 187
Project Lunex 182, 183, 184, 186, 187
Project Mercury 90, 91, 92, 93
Project Orion 178, 179
Project Rheinberry 127, 142
Project Rover 169, 171
Project Spike 109, 110
Project Spiral 149
Project Zement 27, 28
Put-Put 177
Pyramid – Armstrong Whitworth Spaceplane 45, 46, 48
R-1 Missile 29, 143, 148, 149, 168
R-2 Missile 24, 29, 31, 144, 148, 149, 168
R-5 Missile 144, 168
R-7 Launch Vehicle 27, 28, 145, 146, 147, 148, 164, 166, 167, 168
RAE Space Fighter 49, 50
RAF Machrihanish 131, 132, 142
Raketoplan (Rocketplane) 148, 149, 151, 155
RB545 – Rolls-Royce Engine 58, 59, 60, 61
Redstone Missile 66, 68, 69, 91, 108, 127
Rich, Ben 131
Reichsluftfahrtsministerium (RLM – German Air Ministry) 16, 17, 18, 19, 20, 25, 26
RoBo Bell Spaceplane 84, 85
Rods From God 116, 117
ROMBUS – Reusable Orbital Module-Booster & Utility Shuttle 99
Ross, Harry E 30, 41, 42
Ross-Smith Space Glider 42
Sagan, Carl 181, 182
SAINT 109, 120, 122, 168
Sänger, Eugen 32, 35, 37, 55, 76, 82, 85, 117,142, 159
Sänger-Bredt Spaceplane 33, 34, 35, 36, 37, 38, 41, 145, 147
Saunders-Roe Rocketplane 42, 43, 44
Scott-Scott, John 13, 59, 60
Shenlong (Divine Dragon) Test Vehicle 90
Shuttle Orbiter 11, 33, 57, 114
Silbervogel (see Sänger-Bredt Spaceplane) 32, 33, 34, 37, 82, 85
Skoda-Kauba SK P.14 Ramjet Fighter 35
Skylab 97
Skylon 60, 61, 62
Smith, Ralph A 30, 41, 42, 180
Soyuz-(7K)P Perekhvatchik 164
Soyuz-(7K)R Razvedki 164
Space Cruiser 111, 112, 113, 114
Spadeadam Waste, Cumbria 46
Sputnik 1 10, 115
Sputnik 2 10
SR.177 Saunders-Roe 43, 44
SR.53 Saunders-Roe 43, 44
Stanislaw, Ulam 169, 175, 181
Starfish Prime Nuclear Test 108
STS-33/51-L Challenger Shuttle Loss 28th January 1986 11, 102, 114, 115, 137, 139, 142, 155
T-18 Convair 54, 56
Taylor, Dr Theodore (Ted) 175, 176, 178
Test Stand VII 27
Tikhonravov, Mikhail Klavdiyevich 174
Timberwind Nuclear Engine 173, 174
TKS 155, 162, 163, 164, 165
Trans-Atmospheric Vehicle 135
Trudeau, Lt General Arthur G 184, 185
Tsybin, Pavel Vladimirovich 147, 148, 159
Tu-2000A 159
Tupolev Hypersonic Launch Vehicle 150
U-511 Type 1XC Submarine 28
Uragan 152, 153, 155
V-2 Rocket (see A4 Rocket) 8, 19, 20, 22, 23, 29, 66
Vanguard Rocket 10, 65, 105, 115
VfR 14, 15, 25, 32
VKA-1 Spaceplane 147
VKA-2 Spaceplane 147, 148, 150
Volga Optical Unit 161
von Braun, Dr Wernher 8, 9, 10, 14, 15, 16, 17, 18, 19, 20, 21, 25, 26, 27, 28, 29, 32, 35, 37, 38, 39, 40, 41, 42, 63, 64, 65, 68, 69, 70, 119, 143, 178, 180, 184
von Hoefft, Dr Franz 32
von Zborowski, Dr Helmut 17, 25, 35
Vought ASM-135A Missile 109, 110, 111
Vozvrashaemiy Apparat (Return Apparatus, or VA) 161, 163
WAC Corporal 65, 66, 127
Walter HWK 109-509A rocket engine 19
White Sands Missile Range (WSMR) New Mexico 29, 30, 64, 65, 103, 108, 135, 145, 152
Winkler, Johannes 14
WS-199B Rocket (Bold Orion) 107, 108
X-1 Bell 70, 71, 72, 73, 75, 89
X-15 North American 44, 47, 73, 74, 77, 78, 79, 80, 81, 83, 84, 90, 112, 118, 120, 124, 125, 126, 168
X-15A-2 North American 79, 80, 81
X-2 Bell 44, 72, 73, 74, 75, 76, 77
X-20 Dyna-Soar Boeing 49, 50, 85, 86, 87, 88, 89, 90, 91, 93, 97, 120, 123, 124, 133, 137, 139, 149, 150
X-23A 120, 121
X-24A 121, 122
X-24B 122, 124, 126
X-24C-L301 Test Vehicle 112, 124, 125, 126, 127, 128, 129, 133, 142
X-30A 136, 137, 139, 142
X-33 12, 13, 139, 140, 141, 159
X-38 90, 122, 140
XB-70A 138, 139, 150
XSS-10 Microsatellite 116
XSS-11 Microsatellite 116
Yeager, Chuck 71, 72
Yegorov, Aleksandr 189
Zeldovich, Jakov Borisovich 181
Ziegler, Jean 'Skip' 75



RB078B VB-spaceplane



McDonnell Douglas Aerospace Plane



NASA Nuclear Earth - Moon shuttle

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